2 JULY 1958

GAS IN INDUSTRY

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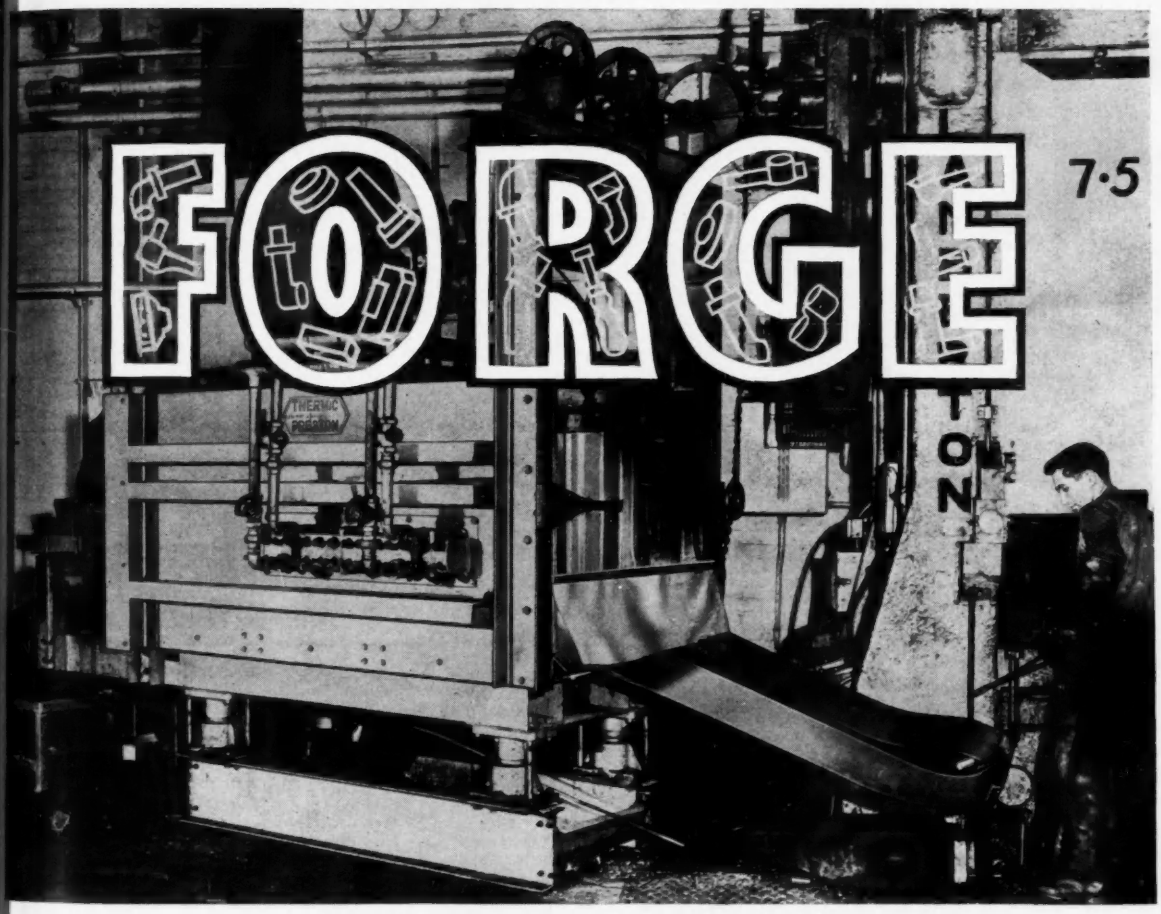
Vol. 1 No. 3

THERMIC

Mechanised



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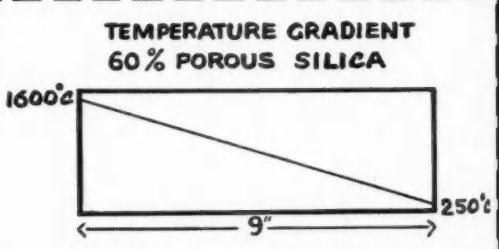

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GAS IN INDUSTRY

JULY 1958

Vol. I **No. 3**

FEATURES

HEAT PROCESSING FERROUS METALS UNDER CONTROLLED ATMOSPHERE CONDITIONS
—By L. A. Lush

THE USE OF SMOKELESS AND DUST-FREE FUEL IN A NEW LENS-MAKING FACTORY AT ST. ASAPH

BETTER INDUSTRIAL CATERING
—By 'Gastronome'

A GAS-FIRED INSTALLATION FOR SUMMER-TIME STEAM RAISING
—By Geoffrey Fitton

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Editorial

Furnace Performance Data

FOR the technician who may be called upon to study regularly the considerable amount of literature and news which becomes available almost daily upon the subject of furnace fuel consumption, production, efficiency and economies, or even for the engineer who may have merely to examine and report upon a single aspect of this vast subject, there is both irritation and legitimate cause for complaint at the haphazard and varying ways in which these facts and figures are commonly presented.

This complaint does not apply only to the selling literature of the small bricklayer-cum-furnace-builder type of concern whose efforts furnish so many good stories for the industry from time to time, but it is also applicable to certain of the more ambitious papers presented to scientific bodies as well as to a type of inspired article which is occasionally encountered in the Press. It has to be admitted, however, that while such examples are quite numerous, the shortcomings are not immediately apparent to the casual reader, who is apt to assume on encountering a mass of figures and statistics that these have been carefully vetted and co-related before presentation.

The acid test applicable to any report of performance is ultimately 'units of fuel per lb. output,' as the commercial criterion of 'pence per lb.' is liable to vary from country to country, or even from district to district, with the local price of fuel. One would imagine that this method of presentation would be an easy matter in either the gas or electrical industry, nevertheless the technician finds in both an irritating lack of uniformity. No scientist could object to the employment of the therm in assessing fuel consumption, even though he might be personally accustomed to thinking and working in cubic feet or gallons, but when one finds three test results published alongside each other with two results expressed in cubic feet per lb. and the other in therms per ton a certain amount of arithmetical conversion becomes necessary as one reads if thorough comprehension is desired. This elucidation of the critical units of fuel per lb. of output becomes considerably more difficult when one result is quoted by *weight* of output, the next in *number of pieces* (both weights and dimensions being unspecified), and a third in *superficial area* of work; the inference in such cases is that the real results are not quite as good as they may superficially appear to be in certain of the methods of presentation. Exasperation, however, is apt to reach a fresh peak when after spending half an hour trying to reduce a mass of figures to some kind of logical order it is discovered that the production stated for '*x weeks*' or '*x months*' is not accompanied by any information or any means of calculating the length of the working day or week, which any layman would immediately recognise as being essential for a study of the subject.

The point may legitimately be made that an apparently high fuel consumption or heavy fuel cost may be more than offset by convenience, by decreased labour charges, or by improved quality of the goods produced, but if such should be the case some information upon these points should be given if the statement is to be accorded due credence. Quality might

in most cases be indicated by 'Percentage of rejects using fuel "A" as compared with the percentage with fuel "B".'

A plea might also be put in for the temperature to be recorded in all cases instead of—as is frequently the case—merely naming the process, melting, annealing, case-hardening, as the case may be. Practice in regard to temperatures for a given process are apt to vary greatly from establishment to establishment with corresponding effects upon fuel consumption and other results. The withholding of a figure for temperature invariably recalls to us a certain type of demonstrator's report, of which we have seen many specimens, that 'A good heat was reached in about two hours,' with an immediate contradiction from someone else that the metal was merely spongy.

Trustworthy

It would at first sight appear to be unnecessary to stress the importance of avoiding arithmetical errors before venturing into print on any subject connected with furnace performance, but experience in analysing and endeavouring to co-relate this kind of data will reveal many such. The usual explanation is that these are to be attributed to a misreading of a slide-rule, but this instrument, impressive as its occasional flourish may be to the uninitiated, is hardly to be recommended as the best of tools for producing results to two or three places of decimals, and the ordinary method of arithmetical calculation—if somewhat more lengthy—is decidedly more trustworthy. A few mistakes in figures of anything up to 20% or more are apt to shake the reader's confidence in the whole exposition.

Adequate

The remedy for this state of things is to be envisaged in two stages. The first is for the general acceptance of a uniform 'code' or method of presentation for all test data and similar results. In this connection, the simple form shown on this page has, over the years, been shown to be entirely adequate for all ordinary purposes in analysing and classifying many thousands of performance figures ranging from grass drying to steel forging. The specimen results recorded on the form may be taken to indicate the minimum amount of information which is necessary in order to justify its recording and classification. The results can, however, be expanded almost indefinitely when one is so fortunate as to encounter what may be termed a 'full dress' test. In this connection a word of warning is advisable against yielding to the temptation to file away a reported result without first proceeding to its complete and logical analysis, as if this is not done the collection will quickly become a mere mass of half-digested technical data which it is impossible to compare without days of preliminary investigation.

The other step in the cure lies in the hands of the secretaries of the societies to which papers of this kind are presented. It is probable that not every secretary of a scientific society is himself a scientist or technician, and even if he is, in view of the difficulty which exists in obtaining a regular and adequate supply of material for presentation to meetings, there may be a temptation not to look a gift horse too closely in the mouth. It is nevertheless the duty of any such official or editor to see that the necessary steps are taken to check over material for arithmetical errors, and further providing the stipulation were made at a sufficiently early stage there are few authors who would raise any serious objection to the presentation of their material and figures in a standardised form on the lines of a British Standard Institute or similar code.

DATA SHEET

PROCESS : Annealing (820°C.) **METAL :** Steel

FURNACE : 3ft. ×5ft. ×2ft. regenerative oven **MAKE :** X. Company

FIRING : Town Gas (455 B.t.u.)

PRESSURES : Gas 2½in. **AIR :** 6in.

CONSUMPTION :

Gas to raise furnace and charge to temp. in ..h.		cu.ft.
Gas to raise furnace and charge to temp. per hour		cu.ft.
Gas to maintain furnace and charge	1st hour	cu.ft.
ditto	2nd hour	cu.ft.
ditto	3rd hour	cu.ft.
Overall gas per lb. of work		cu.ft.
ditto ton		cu.ft.

OUTPUT :

Weight of charge of (20) billets	lb.
Time to bring furnace and charge to temp.	h. min.
Average rate of heating per hour	lb.
Load per square foot of hearth	lb.

SUNDRY DATA :

REMARKS :

Best competitive figures obtained on this process is stated by user to be .,... cu. ft. per lb.

PLACE : Y. Company, Sheffield **DATE** June 24, 19..

Heat Processing Ferrous Metals Under Controlled Atmosphere Conditions

By L. A. LUSH, B.Sc., Assoc. M. Inst. Gas E.

HEADQUARTERS DIVISION, NORTH THAMES GAS BOARD

THE distinction between clean and bright heat treatment is rather one of appearance than of the method of getting the result. Work emerging from a furnace after heat treatment, discoloured or having a slight carbon deposit on the surface may be described as 'clean' whereas 'bright' infers that the surface of the work is not only clean but retains the lustre it had before the treatment. Before describing ways and means by which these finishes may be obtained it is necessary first to try to understand what is happening both chemically and metallurgically. The effect on the surface of the work within a furnace is ultimately dependent upon the atmosphere existing within the heating and cooling chambers, temperature and time. Considering only the more fundamental atmospheres the reactions which occur are chemical or physio-chemical ones and their effects on the metal surface may be:—

(a) None—that is to say the atmosphere is neutral with respect to the surface and no change takes place.
(b) Oxidising — oxygen combines with the metal to form oxides, the effect varying from a thin discoloured film to thick flaky scale.
(c) Reducing—combined oxygen in the oxides is removed resulting in a reversion to the basic metal.
(d) Metallurgical—variation of surface composition by increasing or decreasing the proportions of a constituent, *e.g.*, carbon, within the metal.

It is intended to consider section (d) in greater detail later in the paper and show how the following effects may be brought about by varying the atmosphere conditions.

(i) Carburising, *i.e.*, the addition of carbon to the surface. (ii) Decarburising, *i.e.*, the abstraction of carbon from the surface. (iii) Nitriding, *i.e.*, the addition of nitrogen to the surface to form nitrides in 'nitralloys.'

Complexity

Gaseous chemical reactions. The production of a neutral atmosphere would seem simple enough—just use a gas which is inert to the metal such as argon, helium or nitrogen. Unfortunately, quite apart from cost considerations, which are important, the need for precise control has brought some complexity to the problem. The slightest ingress of oxygen, carbon-dioxide or water vapour immediately upsets the equilibrium to produce oxidising conditions at elevated temperatures and the inert gas is unable to rectify this. Hydrogen and carbon monoxide, however, are both strongly reducing, and by suitable adjustment of the amounts of the oxidising and reducing gases present a balance between the two can be obtained to give a neutral atmosphere. Invariably it is necessary to avoid oxidising conditions and to do this means either eliminating oxygen or nullifying its effect. The simplest methods for the removal of oxygen (O_2) are by combining it with hydrogen (H_2) and/or carbon monoxide (CO) according to the reactions:—

$$2H_2 + O_2 = 2H_2O$$
(Water as vapour) (1)

and $$2CO + O_2 = 2CO_2$$
(Carbon dioxide) (2)

It is sometimes possible to use the heating gases as the furnace atmosphere in which event these reactions occur within the heat treatment chamber. For many processes the heating gases do not come into contact with the work, the atmosphere then being produced from an external generator. This may use town gas or a hydrocarbon gas such as propane (C_3H_8) or butane (C_4H_{10}) burnt with air to produce a mixture of gases containing varying amounts of water vapour, carbon dioxide, hydrogen, carbon monoxide, nitrogen and perhaps small quantities of unchanged hydocarbons. The previously mentioned reactions then take place within the generator, the water vapour and carbon dioxide being subsequently removed from the mixture in varying degrees depending upon the process. Finally under the heading of gaseous reactions we must consider thermal dissociation or 'cracking' of hydrocarbons and of ammonia(NH_3).

The cracking of ammonia is simple,

$$2NH_3 \xrightarrow{\text{Heat}} N_2 + 3H_2 \quad (3)$$

the extent to which the reaction proceeds to the right depending upon the temperature.

In the case of hydrocarbons, 'cracking' results in a breaking up of the molecule to give hydrocarbons of simpler construction if these are possible, together with hydrogen and carbon. In all these reactions the degree of dissociation increases with increase in temperature. Typical oxidation reactions for oxygen, carbon dioxide and water vapour are shown at the top of the next page.

Reactions (6) to (9) are reversible, that is to say, under fixed conditions of temperature and pressure an equilibrium between all components is eventually attained. For practical purposes the pressure may be regarded as constant at atmospheric. Graphs are available shewing the theoretical equilibrium conditions of these equations and from these it is possible to predict in which direction the reaction will proceed at a given temperature. For equations (6) and (7) the equilibrium ratio $H_2O : H_2$ increases with increasing temperature giving the curve a positive slope with oxidising conditions beneath and reducing con-

From a Paper to the London and Southern Junior Gas Association

$$Fe + H_2O = H_2 + FeO \quad (6)$$
$$3FeO + H_2O = H_2 + Fe_3O_4 \quad (7)$$
} Water vapour at elevated temperatures.

$$SFeO + CO_2 = CO + Fe_3O_4 \quad (9)$$
$$Fe + CO_2 = CO + FeO \quad (8)$$
} Carbon dioxide at elevated temperatures.

$$2Fe + O_2 = 2FeO \quad (4)$$
$$4FeO + O_2 = 2Fe_2O_3 \quad (5)$$
} Oxygen

ditions above. Thus, starting from a point in the reducing zone and maintaining a constant $H_2O : H_2$ ratio, progressive reduction in temperature will result in our crossing the curve into the oxidising zone

Negative Slope

A similar curve for the $CO_2 : CO$ ratio against temperature has a negative slope, the reducing properties, for a given ratio, increasing with decreasing temperature. This is the complete reverse of the case given above for H_2 and H_2O and if all four gases are present the reducing and oxidising effects of CO and H_2O respectively, counteract one another to a greater or lesser extent as the temperature falls. Thus a small quantity of water vapour is permissible during cooling in such processes as annealing or normalising without low temperature oxidation taking place. The final and perhaps most important reaction is the readily reversible water gas reaction.

$$CO + H_2O = CO_2 + H_2 \quad (10)$$

As before, the equilibrium condition is finally determined by temperature, but more important is the fact that the concentrations of all four components are interdependent. This means that the elimination by some external means of one component e.g. water vapour from one side of the equation (in this case the left) results in the reaction moving to the left with the production of more carbon monoxide and water vapour. If the water vapour so produced is continuously removed the reaction proceeds as described until only CO_2 or H_2, (depending on which was present in the greater quantity in the first place) remains on the right of the equation and only CO on the left. By the complete removal of one constituent from each side of the equation e.g. CO_2 and H_2O, a stable condition results. Thus far we have concerned ourselves only with the effects of oxidising and reducing conditions on iron and iron oxides. In carburising and decarburising we must examine the effect of the atmosphere on the carbon content of the metal. For this we must refer to the carbon potential of the atmosphere and this may be expressed as the amount of carbon, as a percentage, in the surface of the metal which will remain in equilibrium with the atmosphere, *i.e.*, neither carburise nor decarburise. Although CO is itself weakly carburising the carbon potential is frequently raised by the addition of a free hydrocarbon (propane and butane) to the atmosphere. The surface of the metal acts as a catalyst to 'crack' the hydrocarbon making available nascent, *i.e.*, very active, carbon in intimate contact with the metal surface. If oxygen is present this will extract the carbon, free or combined, to form carbon dioxide.

$$C + O_2 = CO_2 \quad (11)$$
$$O_2 + Fe_3C = 3Fe + CO_2 \quad (12)$$

The removal of carbon in this manner is obviously a decarburising effect. Water vapour, in addition to its oxidising effect on iron, is also strongly decarburising. Its most important effect, however, is to retard the carburising action of the added hydrocarbon gas, reducing the carbon potential. This effect is so marked and is so reliable a yardstick that the measurement of the atmosphere dew point is almost universally accepted as the most rapid means for accurately determining and controlling the carbon potential. Carbon dioxide and hydrogen form water vapour in accordance with the water gas reaction, and hence measurement of the $CO_2 : CO$ ratio may be used as an alternative to give an indirect reading of the dew point. The enriching hydrocarbon e.g. propane reacts with the iron to form iron carbide thus:—

$$C_3H_8 + 9\,Fe = 3Fe_3C + 4H_2$$

The equilibrium conditions for this reaction again depend upon the relative concentrations of the two gases, hydrogen and propane, present. At high temperatures the equilibrium is very much to the right, and a relatively small amount of the hydrocarbon gas will result in the atmosphere being carburising.

Production of atmospheres. 1. Exothermic gas is obtained by the partial or complete combustion of town gas or a hydrocarbon gas, the reaction being self supporting and liberating appreciable quantities of heat. If combustion is almost complete, as with an air : town gas ratio in the range 3.5 : 1 to 4 : 1, the atmosphere is termed lean and consists mainly of nitrogen, carbon dioxide and water vapour with traces of hydrogen and carbon monoxide. This mixture is of little use for ferrous heat treatment processes unless modified to reduce the CO_2 and H_2O contents. As the air : gas ratio is decreased, incomplete combustion results in hydrogen and carbon monoxide being present in increasing quantities. With an air : town gas ratio in the range 2.1 : 1 to 2.6 :1 the atmosphere has fairly high CO and H_2 contents and is termed 'rich.' This is non decarburising and may be used for annealing or normalising low carbon steels and, after the removal of water vapour, for the annealing of medium or high carbon steels. Further purification by the removal of CO_2 enables rich exothermic gas to be used for the annealing of alloy steels with medium or high carbon contents. Purified rich exothermic gas may be used as a carrier for the hydrocarbon gas such as propane to produce a carburising atmosphere.

Visual Flowmeters

Whether a lean or rich atmosphere is required the fuel gas and air pass through visual flowmeters, enabling the air : gas ratio to be readily checked, and are then burnt in a refractory lined combustion chamber. The products pass through a water tube or water contact cooler to remove most of the water vapour formed before being fed, to the sulphur and carbon dioxide removal plants and final drying units if purified gas is required, or direct to the furnace if purification is unnecessary.

2. Endothermic gas is very rich in hydrogen and carbon monoxide, the air : gas ratio being too low to support combustion and, as the name implies, external heat has to be applied to complete the reaction. Water vapour is formed, the amount increasing with increase in the proportion of air to gas, and hence the dew point may be controlled by varying this ratio. A small change, however, results in an appreciable variation in dew point and it is essential that the fuel gas be consistent in quality. For air : town gas the ratio is usually in the range 0.4 : 1 to 0.65 : 1. The fuel gas and air pass through visual flowmeters, then to a proportioning device and compressor and on to the generator itself. This consists of a catalyst filled retort contained in a refractory lined annular chamber heated externally by air blast burners to a temperature in the region of 1,000°C. The resulting products then pass through a water

cooler and are used as an atmosphere for such processes as hardening and annealing of medium or high carbon steels and alloy steels, or used as a carrier gas in carburising, or carbo-nitriding.

Hydrogen Substitute

3. Hydrogen is an extremely inflammable and explosive gas and because of this it is not generally used by itself if an equally suitable and safer substitute can be found. It is, furthermore, quite expensive, and dissociated ammonia containing 75% hydrogen and 25% nitrogen provides a somewhat cheaper substitute. By burning this mixture with air an even greater volume of gases is produced with a lower and therefore safer proportion of hydrogen. The initial dissociation is brought about by passing a stream of ammonia through an externally heated retort containing a catalyst such as pure iron or various forms of metallic nickel at a temperature of 530°C. Applications include sintering and brazing, or the annealing of various steels including stainless steel. In the case of nitriding, dissociation of the ammonia occurs at the surface of the metal to release nascent nitrogen. No dissociation or only partial dissociation is employed prior to passing the gas into the heat treatment chamber.

Measurement of Carbon Potential. There is no empirical formula by which we can decide the atmosphere composition and conditions necessary, to give a pre-determined depth of case by carburising, for each of the many steels used. Certain fundamental facts, such as oxygen and water elimination, follow automatically from what has already been said, but the determination of how much hydrocarbon is to be added to the carrier gas, as well as time and temperature considerations, are largely a matter of trial and error. Sufficient experience, however, has now been gained in this field to decide fairly closely the conditions which will be required. Obviously no attempt should be made to carburise appreciable quantities of expensive machined parts without first knowing what changes are going to take place. The hardness and depth of the case, degree of shrinkage or growth, and distortion are initially all unknown. Several tests are available for determining hardness and depth of case, but the other factors vary with shape of the article and the material from which it is made. Startling though it may seem the growth or shrinkage of similar articles will vary, even though they have the same chemical analysis and are subjected to the same treatment, simply because their basic materials originate from different sources. It is not, therefore, uncommon to hold sufficient raw material, from one source only, to last several months in order to ensure a uniform result with the minimum of testing. Before quantities of articles are produced test pieces are put through the furnace to determine the carbon potential followed by a few, perhaps half a dozen, of the machined articles. These may prove satisfactory, but often the machining operations have to be varied slightly to allow for growth or distortion. In any event it is probable that a second and larger batch will be tested in a similar manner before full scale production commences.

The carbon potential may be measured by treating a test piece under the conditions considered most likely to give the desired result and studying the effect using one or more of the following methods: (a) Hardness measurement, (b) carbon analysis, (c) photomicrographs, (d) weight change. No one of these tests by itself will tell the full story and the choice of which to use is generally governed by the facilities available.

Brinell Scale

(a) Hardness measurement tests are simple, quick and inexpensive, relying on measurement of the indentation on the metal surface by a steel ball or a diamond under standard conditions, the results being quoted as a number on the arbitrary Brinell or Rockwell scales. There are several disadvantages in this method, the main ones being, first that the results cannot be plotted for comparison and secondly, in some cases the hardness may not be affected even if carburisation has occurred. The temperature immediately before quenching and the quenching rate are two very important factors which can affect the final hardness. The equipment for this test, however, is in common use in the laboratories associated with heat treatment, and the hardness is almost invariably measured in this way.

(b) Carbon analysis. A rod or bar of the identical material as will be used for the articles is passed through the furnace on a production run. Thin layers are then removed in succession and the metal cuttings analysed. This test provides information on the rate and depth of penetration, and the carbon content of the first layer gives the carbon potential. Alternatively, thin shims of low carbon steel may be heated for about an hour in the furnace by which time equilibrium will be established between the carbon content of the atmosphere and the steel. As before, determination of the carbon content by analysis gives the carbon potential. These are accurate and very useful tests, but specialised equipment and technicians capable of interpreting the results are necessary. The time taken on each test is quite appreciable and, of course, the sample has to be annealed in an inert atmosphere to avoid variation of the composition, before any machining is carried out.

(c) Photomicrographs are not a very accurate method for determining carbon content particularly where the sample is only slightly carburised, but it has the advantage that it enables a permanent record to be kept. As in the case of carbon analysis technicians are necessary to interpret the results and the tests take time as well as requiring expensive equipment.

(d) Weight change is probably the most accurate of the four tests requiring only a sensitive balance for measuring to .0001 g. The method simply consists of accurately measuring the surface area of small specimens and weighing each one before and after heat treatment. Several variations are possible, one being to use steel specimens having the same carbon content as that which it is desired to produce in the surface of the production articles by carburising. A gain in weight after treatment indicates carburisation and too high a carbon potential. Conversely a loss in weight indicates decarburisation. Of course, scale, carbon deposit, or other foreign matter nullify the results and must always be avoided. The results may be quoted as loss or gain in weight for a given surface area, say 100,000 sq. cm., which thereby puts the values of all samples on the same basis and enables tabulation and plotting for easy comparison.

Rapid Cooling

Hardening and tempering. Hardening of high carbon or carbon alloy steels is brought about by rapid cooling from a high temperature using oil or water as the quenching medium. Articles treated in this way, although hard are also rather brittle and to remove this brittleness tempering is employed. Hardening temperatures are in the ranges 760°-950°C. for plain high carbon and for medium or high carbon alloy steels, and 982°-1,216°C. for high speed tool steels. Rich exothermic or endothermic gas provide suitable atmospheres to prevent scaling at these temperatures. Tempering is carried out over a quite wide range of temperatures below the lower critical point depending upon the ultimate properties required. Scaling is negligible during tempering and it is not usually considered

necessary to provide a protective atmosphere. No purely chemical changes take place during these processes and the physical properties and composition are uniform throughout the article being treated. The risk of distortion on rapid cooling may be slight if the article is large and robust and water quenching can then be employed. With smaller articles, and particularly those of uneven cross section, distortion may be serious if cooling is too rapid and for this reason oil is the usual quenching medium. Either batch or continuous furnaces may be used for the hardening process, the former type being described in the section covering carbo nitriding.

Continuous Process

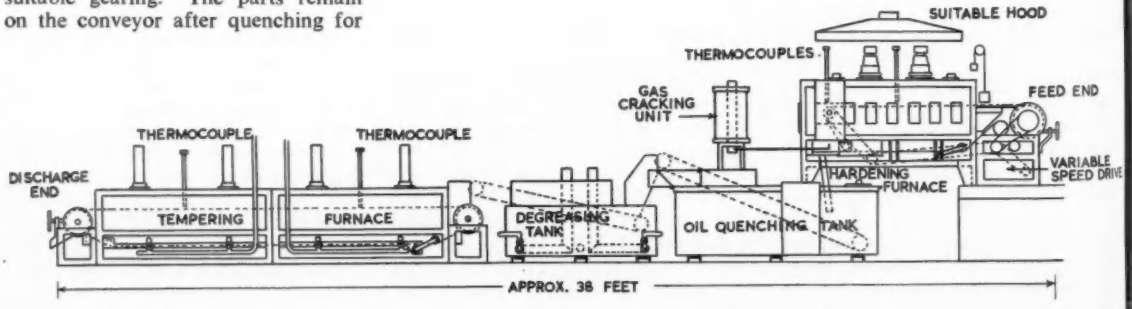
For a number of years several furnaces designed by the Gas Light and Coke Company have been in use in London for the continuous hardening and tempering of small steel parts. A great deal has been learnt from these and similar equipment can be offered with full confidence. The use of protective atmospheres was in its early stages when the first furnaces were constructed and no external generator was used, the combustion products being in contact with the work. The burners are set to give reducing conditions within the furnace with the maximum and minimum gas rate settings differing only very slightly to ensure the least alteration in the composition of the atmosphere. The work is evenly distributed across a 16 in. wide mesh belt driven by an electric motor through a variable speed gear box. The speed of the conveyor varies with the weight of the parts being treated, the hardening temperature of about 800°C. being reached in a few minutes. The conveyor commences its return within the furnace chamber itself, the steel articles falling through a sealed delivery chute into the oil quenching tank, through which passes a further conveyor. This travels at twice the speed of the furnace conveyor and is driven by the same motor through suitable gearing. The parts remain on the conveyor after quenching for sufficient time to be drained of oil before passing to the degreasing tank. A mesh belt in the degreaser delivers the work to the tempering furnace which is controlled at 400°C. over its 14 ft. heating zone. The finished product at the outlet of the tempering furnace is quite clean.

This design of furnace is suitable for bright work if the hardening furnace is indirectly heated by using a muffle, the atmosphere being provided by an endothermic generator. Such a plant is shewn in the accompanying sketch. Although production is simplified by such an arrangement no manufacturers can offer them as standard equipment and the hardening and tempering may then be carried out in separate furnaces. This is the case with one London manufacturer of high grade, high tensile bolts, in the size range ¼ in. to 1¼ in. diameter. These bolts are cold formed from medium carbon and alloy steels such as EN8, EN111 and S.102 and to improve the finish of the bolts without scale formation, hardening is carried out in a controlled atmosphere continuous furnace. The throughput of the furnace is 5 tons each 24 hour day and the plant is at present used 6½ days each week. When starting up from cold it is possible to pass 'commercial' work through in a matter of hours, but an appreciably longer time is necessary to re-establish equilibrium conditions within the furnace chamber to obtain the dull grey finish required for the best work. For this reason the plant is not shut down at week-ends and the atmosphere is maintained at all times.

After machining, the bolts are degreased and evenly distributed on the mesh belt conveyor driven by a variable speed motor. During their passage through a short entry zone the volatile matter is driven off and vented to outside air. This zone also serves to prevent ingress of cold air into the furnace proper, which would rapidly upset atmosphere conditions. The 7 ft. 6 in. long heating section raises the bolts to the quenching temperature of 860°C. in a time largely governed by their size. For those of ¼ in. diameter the conveyor speed is 3.1 in. per min. allowing 29 minutes for the bolts to reach temperature. Heating is provided by 11 4-in. diameter single pass radiant tubes, six above the hearth and the remainder below, firing alternatively from opposite sides of the furnace. Automatic proportioners control the air: gas ratio, and for temperature control purposes the furnace is divided into two zones along its length with a recorder at the quenching end. From the furnace the bolts fall through a sealed chute into the quench tank containing oil. Circulation of the oil is provided by a pump, and a Serck oil cooler maintains the temperature at 40°-45°C. to ensure a constant viscosity. Provision is made to drain the tank of oil and carry out filtration if necessary. A further conveyor passes beneath the delivery chute and sufficient length is out of the oil to give adequate drainage of the bolts before further degreasing and final tempering, both these operations being carried out in separate plant.

Possible Distortion

Distortion may occur if the ratio length: diameter is high, in which event the bolts are straightened to ensure that the dimensions are within the permitted tolerances. The atmosphere requirements of 850-900 cu.ft. per hour are provided by an exothermic generator using town gas. The air: town gas ratio of 2:1 is adjusted using visual flowmeters before the mixture passes to the horizontal combustion chamber. A contact condenser removes a large part of the water vapour produced, the gases then passing through iron oxide purifiers for sulphur removal before being fed to the furnace. Provision is made to admit the atmosphere at various positions along the furnace, but it is found in practice that the point of entry is very critical. To produce the desired finish the majority of the atmosphere



Continuous plant for hardening, tempering, and quenching.

is fed into the chute from the furnace to the quench tank. Thus the furnace chamber is constantly being purged by the gases moving towards the entry, where they are ignited to maintain a curtain of flame across the opening as a further precaution against ingress of air.

Annealing and normalising. These two processes are often confused with one another because some of the objects are the same and the methods employed differ only slightly. In full annealing the metal is subjected to heating to about 50°C. above the upper critical point and 'soaking' at this temperature for times varying from a few hours to several days. Slow cooling is then allowed to take place until below the critical temperature. Work annealing, on the other hand, is designed to remove stresses induced by mechanical pocesses before further pressing or stamping and so on, and here the articles are heated only to the lower critical temperature with subsequent cooling. The main objects of this treatment may be (1) to remove stresses, (2) to induce softness, (3) to refine the grain structure, (4) to improve the ductility or toughness.

Normalising again employs temperatures roughly 50°C. above the upper critical temperature but cooling, in this case is more rapid, generally being carried out in still air. Normalising often follows forging, the main objects then being:—(1) Refinement of grain size either locally or generally. A coarse grained structure may be produced by either overheating, too slow cooling or by finishing the forging operation at too high a temperature, (2) to produce uniform mechanical properties, (3) to improve machineability.

50° C Higher

Using a protective atmosphere and batch type furnaces, annealing can be carried out in a single compartment, with the atmosphere maintained during the cooling cycle at least down to the lower critical temperature. Normalising will obviously require two chambers, one heating and one cooling, with a protective atmosphere to each. The atmospheres vary with the composition of the metal, an exothermic generator using town gas being capable of meeting most requirements. Rich unpurified exothermic gas is suitable for low carbon steels and dry, purified, rich exothermic gas may be used for medium or high carbon steels. For the latter it is essential, of course, to avoid decarburisation. Batch or continuous type furnaces such as are described in the section dealing with carbo-nitriding, carburising or brazing, may be used and it is not intended to discuss this treatment in relation to carbon steels in any further detail. When annealing special steels, for example, stainless steels, there may be special factors to be taken into consideration. Very small amounts of oxygen containing compounds such as CO, CO_2 or H_2O can cause oxidation and must therefore be avoided if the finished product is to remain bright. This can be done by using an atmosphere of cracked ammonia containing 75% hydrogen and 25% nitrogen. Due to the high hydrogen content this atmosphere may be dangerous to handle if the capacity of the furnace is appreciable. The hydrogen : nitrogen ratio may be reduced by partially burning the mixture with air followed by cooling with a water cooler and final drying using silica gel units. Apart from safety considerations partial burning also has the advantage of lowering the cost, since it results in a greater volume of atmosphere being obtained from a given initial volume of ammonia gas. The temperatures employed are in the range 900°-1,150°C. and rapid cooling is essential to prevent weld decay and intercrystalline corrosion.

Electrode Guns

The North Thames Gas Board recently constructed a small furnace for the manufacture of parts for the electrode guns of cathode ray tubes, and a description of this plant will serve to illustrate the process. Preliminary tests were made using a considerably modified G.L.C. muffle tube furnace to which air blast burners were fitted, and the silica tube replaced by one of 2 in. diameter and made from 18/8 nickel chrome steel. After a trial period this shewed the principle to be satisfactory and work was commenced on a twin tube furnace designed for the job. The ammonia, from central storage bottles, is passed through an electrically heated cracker unit operating at 530°C. with a rating of 1.5 to 3.2 kW, providing an output of about 60 cu.ft. per hour of atmosphere for each furnace tube. The annealing furnace itself comprises two sections, a hot zone 44 in. long and water jacketed cooling section 42 in. long. An air supply is available at 100 lb. per sq. in. gauge, this pressure being reduced to ½-1 lb. per sq. in. gauge by a needle valve and an injector before passing to the air/gas proportioning device serving the six ¼ in. burners sited in staggered formation on opposite walls of the furnace. A gas rate of approximately 400 cu.ft. per hour is required for the operating temperature of 1,150-1,200°C., temperature indication being by a pyrometer inserted through one end of the furnace. Two 2-in. diameter nickel-chrome steel tubes in the same horizontal plane pass through the furnace and a flanged joint is made at the exit end to mild steel tubes in the cooling section. The atmosphere connections are made between the two zones, the nitrogen/hydrogen mixture discharging at opposite ends of the tubes where it is ignited by permanent pilots. The parts are loaded, four at a time, in small boats 5 in. long and manually pushed into the tubes moving all those inside the furnace the same distance forward. Once temperature has been reached and given sufficient heat input, parts can be fed through the furnace quite rapidly. In fact, about 5,000 parts per tube per day is the normal operating capacity.

Carburising and Carbon Restoration. These two processes are amongst the most interesting where controlled atmospheres are employed. Much has already been written about various plants installed throughout the country, but I feel there is no harm in repeating some of this, and if read in conjunction with my opening remarks a fairly complete picture of the requirements will, I hope, be obtained. It is gratifying to know that town gas is almost universally chosen as the heating medium for these plants, although electricity and oil fuel can be and are used. The purpose of the carburising process is to increase the carbon content in the surface layers of an article without affecting the composition of the core. In this way the surface can be hardened with resulting increased resistance to wear while the core retains the toughness desired in such articles as gears, pinions and cams. It is still quite common to find pack carburising, in which the articles are in close contact with a carbon laden solid medium, but of recent years there has been a definite preference shewn, particularly for large installations, for carburising using a gas as the medium. There are, however, a number of manufacturers now producing a range of batch type gas carburising furnaces which can be used for smaller production runs. Generally the smallest economical throughput is around 200 lb. per hour and unless this output can be maintained the capital and running costs of the equipment, including atmosphere generator, are still too high for many of the smaller firms.

Nascent Carbon

In both pack and gas carburising the object is to provide at the surface of the metal nascent carbon, *i.e.*, carbon in the atomic state and its most active form. The depth of carburisation is mainly dependent upon the operating

temperature and the time for which the article is in contact with the carburising medium. In gas carburising the degree of carburisation is governed by the carbon potential of the gas which takes into consideration the presence of such decarburising media as water vapour and carbon dioxide. If carbon is deposited on the metal surface as fine particles then, contrary to what one might expect, carbon absorption is inhibited and this connection is therefore avoided if possible. With gas carburising strict and accurate control over the carburising atmosphere is essential. This atmosphere may be produced using burnt town gas or burnt hydrocarbon gas, with subsequent enrichment to obtain the desired carbon potential. A town gas exothermic generator produces a mixture of gases containing appreciable quantities of carbon dioxide and water vapour. A large part of the latter is removed by condensation, and that remaining, together with the carbon dioxide, can then be reduced by charcoal at about 950°C. The resultant gas contains approximately 25% CO, 3% H_2 and the balance N_2 with a dew point of about −40°C. This should be regarded only as an example of carrier gas production as no hard and fast rules can be laid down stipulating the percentages of CO and H_2 necessary. From whichever source the carrier gas is obtained the carbon potential can be adjusted as already mentioned.

Catalytic Removal

If sulphur compounds are present the sulphur may be reduced to negligible proportions by a catalytic removal plant sited before, or iron oxide purifiers sited after, the generator. In some cases it may be necessary to incorporate both of these. If all these precautions are required in order to 'condition' the atmosphere it will be appreciated that capital outlay and maintenance costs will both be increased. The chemical composition of town gas, however, can and does vary from time to time and this may result in variations in the quality of the atmosphere produced from it. For this reason the use of one of the lower hydrocarbons, propane, or butane, is frequently preferred as these can be purchased in bulk and a high degree of purity guaranteed. An endothermic generator is employed for the cracking process, the air:gas ratio setting depending upon the hydrocarbon chosen and on the composition and dew point desired in the resulting atmosphere. As in the case of partially burnt town gas this atmosphere is enriched by the addition of small quantities of a hydrocarbon which lowers the dew point and increases the carbon potential to the order of .8%C. The process of carbon restoration appears to be carried out only on a limited scale in this country but I feel that it is worthy of mention. During such mechanical processes as stamping or rolling, the surface of the metal becomes decarburised and it may be desirable to restore the carbon content of such decarburised areas to obtain uniform composition throughout the article. The process employs a carburising atmosphere but the carbon potential is only equivalent to the carbon content of the core, and not higher as is the case in carburising. Thus, once the carbon content of the previously decarburised surface reaches that of the core no further absorption takes place irrespective of the length of time employed.

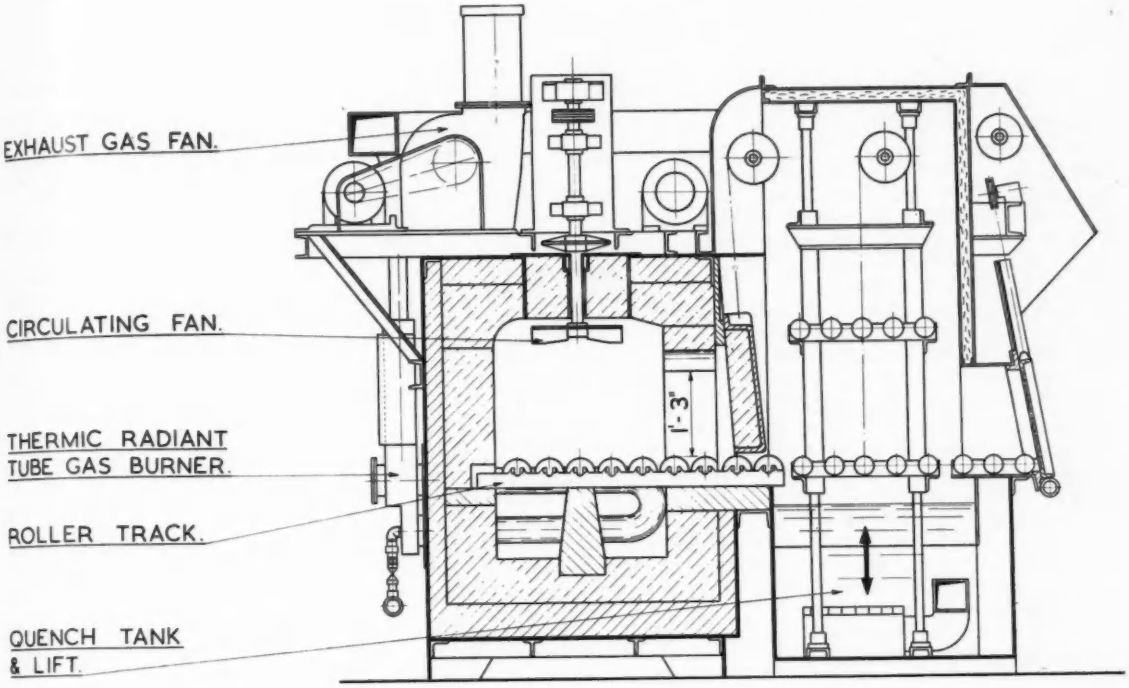
Plant designed for carburising is usually equally suitable for other types of clean heat processing such as annealing or carbo-nitriding, always provided, of course, that the time cycle can be adjusted accordingly and that the atmosphere generator is capable of meeting the different requirements. One large engineering company in London has for many years been engaged in the manufacture of a multitude of different types of gear. The majority of these are of alloy steel which, until recently, were treated in pack carburising furnaces to give the necessary surface hardness. A limited amount of work is still treated in this manner, but with the installation of a three track continuous pusher type, gas carburising furnace, production has been considerably streamlined with appreciable savings in space and labour, and with improvement in the quality and consistency of the work. The plant itself is a compact unit comprising charge vestibule, furnace chamber, discharge vestibule, quenching tank and washing plant. Once the controls have been set all carburising operations, with the exception of loading and unloading the gears, may be automatic. With some gears distortion may occur during carburising, press quenching is then employed in place of the automatic quench to ensure that the dimensions of the work are within the permitted tolerances. When press quenching is used, five machines enable the operators to rapidly unload the gears from the carriers.

After cutting, the gears are washed to remove all traces of oil and other foreign matter from the surface and then manually loaded on to 18 in. square heat resisting steel trays each capable of carrying up to 150 lb. of gears. Three such loaded trays are transferred to a trolley which has previously been withdrawn from the charging vestibule. The trolley is returned, the door closed, and the vestibule purged for a controlled two and a half minutes. An important point to note here is that the purge timer overrides all other controls connected with the sequence of operation at the loading end. A control panel to one side of the furnace incorporates an automatic timer with warning bell and light for each of the three tracks. This system enables the operators to see at a glance which track is ready for the next push. The furnace chamber itself is 31 ft. long, 6 ft. wide and 6 ft. high with transverse gas-fired radiant tubes above and below the hearth, giving a combined maximum gas rate of the order of 4,000 cu.ft. per hour. In practice it has been found that about 2,800 cu.ft. per hour satisfies most throughputs.

Four Zones

For temperature and atmosphere control purposes the furnace length is divided into four zones. The first zone serves to preheat the cold work entering the furnace and for this reason has the highest gas rate. About 500 cu.ft. per hour of atmosphere gas is fed to this zone with 1% propane enrichment which commences the carburising process. The temperature varies between 880°C. and 900°C. depending upon the case depth required and the time cycle. The second and third zones are the main carburising ones, the atmosphere requirements being 500 cu.ft. per hour and 300 cu.ft. per hour respectively. The desired carbon potential of about .8% and a dew point of between 10°F. and 15°F. are obtained by 1-2% propane enrichment. Circulating fans in the roof of the furnace ensure even distribution of the gas to give uniform carburising. Medium case depths of between .035 in. and .040 in. are obtained with a temperature of 900°C. while for deeper cases in the range of .055 in. to .060 in. the temperature is raised to 920°C. The final zone cools the work to the quenching temperature of 850°C. No neat propane is added to the 300 cu.ft. per hour of atmosphere gas serving this section. The time cycle within the furnace chamber varies from about nine hours at 900°C. for the majority of the work, giving medium case depths, to just over 12 hours at the higher temperature for the deepest cases. With the shorter cycle a throughput of about 600 lb. per hour is achieved.

For the atmosphere, three endothermic generators are installed, only two being in use at any given time with the third as standby. One, in continuous operation, produces 1,600 cu.ft. per hour of endothermic gas to



A typical batch furnace showing entrance vestibule and processing furnace.

serve the furnace chamber (1,500 cu.ft. per hour) and purge the pusher rams (100 cu.ft. per hour). The second is in intermittent use to produce at roughly 1,200 cu.ft. per hour, which is a sufficient output to purge the charge and discharge vestibles when the doors have been closed following loading and unloading. The generators are worked in rotation so that no one is on standby indefinitely nor one in continuous use. Town gas is used to heat the retorts which operate at a temperature of 1,050°C. The dew point of the generated atmosphere is measured by a Foxborough Dewcel recorder and kept at about 30°F. by varying the quantity of air to a constant 125 cu.ft. per hour of propane. The atmosphere is highly carburising and deposits on the surface of the work a very thin layer of carbon which is subsequently removed by shot blasting. Unless there is a serious fault, such as leakage in the water cooling system, it has been found that the dew point of the furnace atmosphere remains fairly constant. Samples taken from different positions in the furnace show little variation and tests are made in the morning, midday and later afternoon from one zone only, generally the third, using an Alnor portable dewpoint indicator. A check is kept on the case depth and hardness by passing a sample piece through the furnace every two hours. Once each month a more thorough test is made using a 1 in. diameter bar as the test piece and, after treatment, the surface is skimmed to find the carbon gradient through the case. Since it takes two to three days to reach temperature from cold, and a further similar time to recover the characteristics of the atmosphere, the plant is never allowed to go out, except in the event of a breakdown, or to burn out the accumulated carbon deposit on the inner surfaces of the furnace chamber. This is carried out at four-monthly intervals.

Approximately 25 cwt. of propane are used each week, and is delivered in bulk roughly every third week in 4-ton lots. The quenching oil for this and other plant in the factory is stored in a 10,000 gal. undergound tank and kept in condition by a cooler and centrifuge. The latter removes suspended and near colloidal carbon from 500 gal. of the oil each hour, the inlet and outlet connections to the tank being some distance apart. The floor space taken up by the complete plant is about a quarter of that required by the older pack type carburising furnaces and nine semi-skilled operators now do on a shift basis the work for which 34 men were previously employed. This one plant alone caters for over a third of the heat treated output of the firm.

Carbo Nitriding. This process is a combination of carburising and nitriding whereby both carbon and nitrogen are absorbed to produce a hard case with high wear resistance. The function of the nitrogen is (1) to increase the resistance to wear, (2) to permit the use of a milder quench by progressively reducing the critical cooling velocity of the case (3) by continuous absorption, and the progressive lowering of the critical temperature of the case to enable the use of a lower case hardening temperature.

It will be appreciated that as a result of (2) and (3) above there is also less risk of distortion. Case depths are very much less than is usual with carburising being generally in the range .002 in. to .025 in. with times at temperature (770°C. to 870°C.) varying from about 20 minutes up to 2½ hours. The atmosphere employed is produced from an endothermic generator using a gas such as propane or butane with subsequent enrichment by small quantities of ammonia and uncracked hydrocarbon.

A typical batch furnace is shown in the accompanying sketch and it will be seen that this consists of two separate chambers, a hot zone heated by radiant tubes and a water jacketed discharge vestibule, these being separated by an inner door. One of the largest installations of its kind in

Europe is installed in an automobile factory in this country. Eight batch-type furnaces in a line are used for carburising and carbo-nitriding.

Each furnace chamber is approximately 38 in. cube, heating being provided by eight vertical 6-in. diameter tubes, four on each side wall. The maximum combined gas rate of these is 1,000-1,200 cu.ft. per hour of 500 B.t.u. gas, and a common thermostat is used to control the temperature to between 700°C. and 900°C. depending upon the process. A shield placed around the stock in the furnace reduces direct radiation from the tubes, which would otherwise give rise to uneven heating. A single supply line passes the atmosphere into this chamber through one of the side walls and the circulating fan with a water-cooled shaft is sited in the roof. A small hole of about ¼ in. diameter is made in the inner door connecting the two chambers enabling the furnace atmosphere to pass into the loading vestibule and keeping this purged. A further hole in the loading door releases the gas to free air, where it is ignited by a town gas curtain constantly maintained to prevent the ingress of air when the door is opened for loading and unloading. When starting up the plant the atmosphere is not admitted until a safe working temperature of about 700°C. is attained within the furnace. At this temperature the atmosphere ignites on entry to the chamber and burns with the air present. This procedure must always be adopted where inflammable atmospheres are used as, if the gas does not ignite on entry, explosive conditions could be created. Two endothermic generators are positioned centrally in the row of furnaces, being used alternately to produce an atmosphere which is neutral to the steel being treated. The normal operating temperature of 1,050°-1,070°C. is obtained using four air blast town gas burners firing tangentially around the central nickel-chrome retort containing the nickel catalyst. Butane and air in the ratio 9:1 are passed through the retort to produce a gas containing .2%-.6% CO_2 and having a dew point 27° to 37°F. Under normal working conditions each furnace requires approximately 225 cu.ft. per hour of carrier gas so that the generator in use is producing approximately 1,800 cu.ft. per hour. No subsequent drying or other purification is employed. This is fed at 12 in. w.g. into a supply line running behind the row of furnaces. It is found that after 168 hours, *i.e.*, one week, of continuous operation the catalyst becomes heavily sooted, causing a back pressure on the inlet to the retort, and the other generator is then switched in. The soot is removed by decreasing the temperature to about 750°C., shutting off the butane supply and passing air only through the catalyst at about 10% of the rated flow until no CO_2 can be detected in the outlet gases, which are discharged to atmosphere. This operation is generally complete after about 24 hours. The butane is stored well away from the furnaces in four bulk containers each holding one ton of liquid butane. Only one is in use at a time, the outlet pressure being reduced by a governor to 10 lb. per sq. in. gauge before being fed into the transmission line to the generators. If the demand is high and the ambient temperature below 50°F. the butane can freeze and to prevent this the container in use is externally heated by steam. At the end of each container, and arranged vertically, are four small sampling holes. Frequent checks are made to determine the level of liquid for, since pressure is maintained until no liquid whatsoever remains, pressure gauges are useless as an indication of the gas in hand.

Drop in Temperature

The work is degreased and jigged in nickel chrome trays before being manually transferred into the loading vestibule where it remains for slight preheating before being passed into the furnace chamber. The entry of the cold work causes a considerable drop in temperature, the recovery time depending upon the weight of the charge, being roughly one hour for a load of 800 lb. The neutral atmosphere is maintained during this period and when temperature has been restored the ammonia and butane are added, the quantities being 10-12 cu.ft. per hour and 2-4 cu.ft. per hour respectively to 225 cu.ft. per hour of the carrier gas. Time at temperature is ½-2 hours, depending upon the material to give case depths in the range .003 in. to .018 in. The work is then removed from the furnace on to the elevator and lowered into the built-in quench tank. This is provided with a motor-driven agitating propeller circulating the oil through the work, the oil temperature being maintained at 55°-75°C. by an integral cooler. The hardness obtained is greater than by carburising but direct comparisons are difficult due to the much lighter case depths. Among the parts treated are cotter and king pins, transmission shafts, layshafts, speedometer and water pump gears.

Nitriding. It is as unfortunate as it is unexplained that the furnaces used for this quite widely practised and interesting process are almost always electrically heated. Nitriding is not a new process by any means and that this state of affairs can exist is something we in the gas industry must carefully examine. It is appreciated that the temperatures used are in the most difficult control range, if direct firing is employed, and only small variations are permissible. For quite a long time though, we have had hot air circulating ovens available which are capable of working under just the conditions required and there would seem to be no reason why this principle should not be adopted for nitriding furnaces. In nitriding, as in carburising, the object is to produce a thin but extremely hard case on the wearing surface of articles by employing a gaseous medium to form nitrides. Examination under a microscope shows a nitrided surface to consist of thin needle like crystals hard enough to scratch glass and even quartz, having a very high resistance to wear and showing considerable resistance to the corrosive action of steam, sea water, or a damp atmosphere, but not against mineral acids. These hardness and resistance properties are retained even at the high working temperature of 500°C. and for short periods at 650°C. Typical diamond hardness figures for nitrided alloy steels are 1,050-1,150 as against 750-850 for case hardened carbon steel and 800-900 for a hardened high speed steel tool bit. As there is no effect on the surface finish and little, if any, distortion, nitriding is generally carried out on the finished article. A small grinding allowance (.002 to .003 in.), removed after nitriding, is usual on surfaces requiring the highest accuracy and hardness.

The sequence for a large forged part would be as follows:—

(1) Rough machine.
(2) Heat to 950°C. and quench in oil, temper at 540°C. to 700°C. according to core strength required.
(3) Machine to within ⅛ in. of finished dimensions.
(4) Stabilise at 550°C. to remove stresses.
(5) Finish machine and/or grind.
(6) Nitride.
(7) Grind or polish working surfaces.

As bar material is supplied in the heat treated condition, operations 1 and 2 are unnecessary on most work. The process time is long, 20 hours producing a case depth of about .008 in. and 90 hours about .031 in., but the cost compares favourably with other processes, with the additional advantage of a minimum finishing cost. During nitriding there is an increase in volume of the case, with a consequent increase in dimensions of the parts. The increase is dependent on area and volume of the parts and amounts to between .0005 and .001 in. on solid bar diameters and proportionately more on lengths and hollow

sections. It is a constant amount for a particular part and can be estimated and allowed for in manufacture, where necessary. In parts of uneven cross section the extent of growth will vary and this can give rise to distortion. If necessary, parts can be straightened by hot pressing, although this must be carried out with due regard paid to the risk of cracking the case. The articles are packed within a sealed container, generally of Inconel, and provided with a lid which is bolted and sealed in position to prevent egress of the atmosphere. Ths may be either undissociated or partially dissociated ammonia according to the method of working and the results required. In either case the medium is admitted to the container through a delivery tube which passes through the furnace wall and a similar connection is made to provide an exit for the spent gases.

Catalyse Dissociated

At the temperatures employed, around 500°C., the surfaces of the parts to be nitrided catalyse dissociation of the ammonia to provide nascent nitrogen in intimate contact with the metal, the resulting reaction forming nitrides. Considerable research has been carried out to determine the nature of the steels most suitable for nitriding. The most successful results are obtained using steels containing varying amounts of such metals as chromium, aluminium, nickel, molybdenum, vanadium, etc., which are all capable of forming nitrides.

A large engineering company in London has been carrying out nitriding on a contract basis for many years using three electric furnaces, and a clearer picture of the process details will be obtained if a description is given of the plant and methods used. Standard nitriding times are 50 hours at temperature to give a case depth .012 in. to .015 in. and 80 hours for a case depth of .018 in. to .025 in. Either one or the other meets most clients requirements. The articles are first degreased by trichlorethylene and any part of a surface not to be nitrided is coated with a tin based paint before packing in one of the Inconel gas-tight boxes used. Nickel grids separate the loaded parts to ensure free circulation of the ammonia gas which is fed into the container through the delivery tube along one side at low level and which extends to pass through a hole in the back wall of the furnace. Connection is made by a flexible hose to an ammonia line from a central storage. The atmosphere discharge is taken from the opposite corner of the container with a further flexible connection made to two bottles in series. The first of these is dry and the second contains water to absorb undissociated ammonia and provide a back pressure of about 1 in. w.g. The free nitrogen and hydrogen are discharged to atmosphere. Approximately every two hours the discharge gases are analysed to determine the degree of dissociation. This is carried out by first admitting the gas mixture into a 100 c.c. graduated chamber and expelling the air. Water is then allowed to flow in from a reservoir and this immediately absorbs the ammonia, the water continuing to enter the chamber until it takes up the same volume as that previously occupied by the ammonia gas. The atmosphere above the water is insoluble hydrogen and nitrogen gases in the ratio 3:1 and the volume of this mixture immediately gives the degree of dissociation, which is normally of the order 24-25%. Fans are sometimes employed to ensure even temperature distribution, the temperature being maintained to within ±5°C., but a satisfactory finish is obtained in some furnaces without their use. Heating is by elements provided on five sides of the furnace, only the rear wall being unheated. Two pyrometers are used, one passing through the rear wall into the loaded container and the other measuring and controlling the furnace temperature.

Rating Reduced

The heating up time for these furnaces varies from 7 to 10 hours depending upon the weight of the charge, the furnace rating during this period being 40 kW. When the charge has reached temperature a switch enables the rating to be decreased to 15 kW. which reduces 'hunting.' The two large furnaces have containers 6 ft. 4 in. long, 4 ft. wide and 1 ft. 9 in. deep so that the longest part that can be accommodated across the diagonal is about 7 ft. 6 in. If parts to be treated are heavily oxidised, nitriding is inhibited and spalling will occur. A thin film of oxide, however, is reduced to the metal and does not appear to materially affect the result. This process has many applications for parts requiring high wear resistance and operating under high temperature conditions such as exist in, for example, aircraft engines. Cylinder barrels, crankshafts, gudgeon pins, steam valves are typical of the many items treated in this manner.

Furnace brazing. Many steel parts of complicated structure would be difficult, and often impossible, to manufacture by normal production machining and pressing processes. The problem is simplified by fabricating such parts from two or more separate units which can be easily and simply made and later brazed together, using as the brazing medium copper, copper bronze or silver bronze, all of which have appreciably lower melting points than steel. When the medium becomes molten it flows by capillary action between the faces of the parts which are in close contact. The condition of the surfaces must be clean, and trichlorethylene is a satisfactory agent for this purpose. The process is carried out in an atmosphere which is neutral to both the steel and brazing medium, at temperatures from 1,100°-1,150°C. If a flux is used the temperature may be about 200°C. lower, but this method has the disadvantage that the part requires subsequent cleaning for removal of the excess flux. While gas fired furnaces are available, using the radiant tube principle, which are capable of reaching approximately 1,130°C. in the working space, it would seem that generally the life of the tubes, operating continually at 1,250°-1,300°C. to give this working temperature, is short, and investigation into the subject is continuing. The brazing of the more common non-ferrous metals can be carried out at temperatures appreciably below 1,000°C. and gas can satisfactorily meet the requirements, but electrically heated furnaces are usually favoured for the higher temperature range 1,100°-1,150°C. With or without flux the furnace atmosphere requirements are similar and can be provided by a town gas exothermic generator, generally with catalytic or iron oxide sulphur removal units. Continuous brazing by conveyor furnaces is a fairly simple process to produce complicated articles quickly and at a lower cost than by other methods. Its use could, therefore, expand and it is to be hoped that we shall shortly be in a position to offer, with full confidence, plant for this duty.

Buffer Against Draughts

An electrically heated conveyor furnace installed in a large factory in North London consists of entry, heating, and cooling zones which are 3 ft. 9 in., 7 ft., and 14 ft. long respectively. The first of these serves only as a buffer against draughts which would otherwise upset the atmosphere conditions within the heating zone. An atmosphere connection is made to ensure that it is constantly purged, the gases moving towards the front opening where they are ignited by a permanent pilot. The heating or furnace

zone has electrical elements giving a maximum rating of 35 kW. (approximately 120,000 B.t.u. per hour) and the operating temperature, using pure copper without flux as the brazing medium, is 1,140°C. To safeguard the furnace against accidental overheating, due to a temperature control instrument failure, an excess temperature cut-out, in the form of a gold alloy fuse breaking at 1,160°C., is positioned within the furnace. The atmosphere is fed in through a supply line in the top of the furnace. After passing through the furnace the parts enter the 14 ft. long water jacketed cooling zone. This again has its own atmosphere connection with permanent pilot at the exit to ignite the gases. The 8 in. wide mattress conveyor passes through each section and is returned beneath the furnace by way of a tension roller. The use of jigs is avoided where possible and either staking pins or a spun edge used to secure the mating parts in position. It will readily be appreciated that, if the conveyor vibrates during its passage through the furnace, the relative positions of the components being brazed together will vary. For this reason great care must be given in the design to ensure absence of vibration from the motor, gearbox or the conveyor itself and the importance of achieving this cannot be over-emphasised. In this plant smooth running is ensured by using a Carter gearbox which is infinitely variable within the conveyor speed range 0 to 12½ in. per minute.

Elaborate Ancillaries

The atmosphere requirements of 870-900 cu.ft. per hour are provided by an exothermic generator using town gas as the fuel. This is quite an elaborate ancillary and comprises (1) an air/town gas proportioner and compressor, (2) a combustion chamber, (3) a water tube cooling and condensing tower, (4) bog ore sulphur removal boxes (two), (5) silica gel final drying units (two). The proportioner is fitted with a vernier adjustment for the air/town gas ratio giving an atmosphere containing approximately 6% CO_2, 8% CO, 10% H_2 free from oxygen and the balance N_2. The air/gas mixture is supplied to the combustion chamber at a pressure of 20 in. w.g. (0.7 lb. per sq. in. gauge) by way of an oil trap. A large proportion of the water present in the exit gases is then condensed out by the water tube cooler and the bulk of the sulphur present removed by the iron oxide purifiers. The small quantity of sulphur remaining does not appear to have any harmful effect on the finished product. Finally, all traces of water present are removed by a silica gel drying unit. A fan blows air through a heat interchanger around the ducting carrying the burnt gases from the combustion chamber, and the heated air so obtained is used to dry the silica gel in the unit which has become inactive through previous use. This generator supplies other equipment in the heat treatment shop apart from the brazing furnace described. An enormous variety of parts for such automobile and aircraft accessories as clocks and speedometers are treated in this furnace. The approximate weight output is 60 lb. per hour but this varies with the belt speed and size of the component, the numbers treated running well into six figures each month.

Sintering and powder metallurgy. While limited in its application the manufacture of articles from metal powders provides some of the most interesting developments of recent years in production engineering. If we confine ourselves purely to the heating requirements the process seems simple enough, but the techniques employed before the articles reach the actual sintering stage merit at least some mention although we are not directly concerned with them. Sintering itself is a very old process, and according to some authorities it goes back to about 6,000 B.C., but it was not until about the 1930s that the need to mass produce small articles with a minimum of machining and finishing stimulated research into some other means for their production, and resulted in enormous strides being made in powder metallurgy and sintering techniques. Originally almost all of the powders used for ferrous parts was obtained from Sweden as a by-product of the manufacture of iron ingots from the exceptionally clean and pure iron ores which exist there. The ingots, which are further refined for the production of high grade steels, are obtained on direct reduction of the iron oxides in the ore by charcoal. From this process there remain appreciable quantities of iron dust, which do not coalesce with the ingots and which, if fed to the purifying furnaces, are imediately oxidised and lost. Today, this dust is recovered and the powders produced from it are ideally suited to the sintering process. The majority of the iron powders used are still produced in this way, but several other techniques have been devised for their production, the two most important being electrolysis and atomisation. Though we are obviously not concerned with the electrolytic method, gas may be used in connection with atomisation. In one instance a typical sequence of operation starting from the raw material is as follows. Mild steel, with a carbon content of .1% or less is mixed with a controlled amount of carbon and melted in electric arc furnaces before being poured into ladles. The melt is then passed through a small orifice to give a molten stream which is dispersed into fine particles by a jet of compressed air. These particles fall into a large tank containing water and immediately solidify into a sludge at the bottom. During this process the smaller particles and the surface of the larger ones become oxidised. The sludge is removed manually and after draining is passed through a gas fired rotary drier before being ground in a ball mill to further reduce their size. Different manufacturers may use considerably different methods; the decision to add further carbon will be largely governed by the analysis of the raw material and the required characteristics of the resulting powder, electric induction or ordinary cupola furnaces may be used for initial melting, dispersion of the molten stream may be by a jet of water instead of compressed air, and so on. The dried powder is then fed onto a conveyor carrying it through a muffle furnace heated to 1,000°C. In this way the carbon which has remained in the mixture reduces the oxides and forms carbon monoxide, leaving the metal powder with a composition of mild steel, namely .04% to .1% of carbon. The carbon monoxide given off forms a self protecting atmosphere, but under certain conditions insufficient is produced and lean exothermic gas from a generator or, more usually, a hydrogen/nitrogen mixture from cracked ammonia, then added as a supplement.

Irregular Shapes Better

Certain physical features are desirable in the powders used, the most important being their size and shape. The particles are not all of one size being generally not larger than will pass through a 100 mesh sieve and more usually passing 200 mesh. The more irregular shapes have the better compacting qualities which is the reason for the preference given to powders produced by chemical reduction or electrolytic methods. The atomisation process described gives roughly spherical particles which cost rather less to produce but are not suitable in many cases. A lubricant, frequently stearic acid and/or zinc stearate, is homogeneously blended with the powder in order to increase die life, the blending time being generally limited to 15-20 minutes to minimise loss of shape of the particles. Carefully measured quantities of the mixed powders are pressed between dies at pressures upwards of

15 tons per sq. in. to produce the 'green compact' which must be sufficiently robust to withstand subsequent handling. In order to test this property or 'green strength' a small number of compacts may be rumbled together and the loss of weight subsequently measured. This may be as little as 1%, or even less, after about 1,000 revolutions. Other tests carried out to determine the characteristics of the powders include compressibility, density and packability. A high compacting pressure is desirable but is usually limited because of the increased wear on the very expensive dies used. Pressures up to 50 tons per sq. in. are quite common, the size of the parts produced then being limited largely by the size of the press. Generally the surface area, taken as the area at right angles to the direction of pressing, is only a few square inches. Output rates vary with the design of press; with automatic powder fillers and ejectors and using multiple dies several thousand pieces per hour can be obtained from one machine.

Shales Limited

Metal powders possess poor lateral flow properties and for this reason rebates, re-entrant angles and so on cannot be moulded. Sharply tapering dies with wafer thin edges will not withstand the high pressures used and, of course, must not meet during compacting. For these reasons bevelled edges less than about 30° and complete spherical shapes are not possible. The extent of compression varies with the distance from the die face and therefore limits the thickness of the parts made. These are a few of the points requiring consideration and which serve to shew the importance of correct die design. The 'numbers off' have to be appreciable to justify the high die costs and about 10,000 is often regarded as an economical minimum quantity. From the presses, the compacts are passed through the sintering furnace and heated to a temperature between 1,000°C. and 1,400°C. Tolerances of ±0.005 in. can quite readily be attained by one pressing and sintering, and by a second pressing or 'coining,' followed by a further sintering, this can be reduced ±0.002 in. or less. The virtual elimination of scrap loss by avoiding subsequent machining operations, is often in itself sufficient justification for employing this method. Densities approaching theoretical are possible if two pressings with high die pressures are used and the parts may subsequently be subjected to such treatment as carburising or carbonitriding, under conditions already described, if it is necessary to increase the surface hardness.

As regards the sintering furnaces themselves, these should be capable of attaining temperatures in the range 1,000°-1,400°C. under controlled reducing atmosphere conditions. For temperatures of up to approximately 1,150°C. the compacts may be loaded direct onto the belt; above this temperature furnaces of the pushed tray type are used. These may be inclined to the horizontal to prevent 'suck back' of the highly inflammable reducing atmosphere on opening the furnace door, the inclination also serving to reduce the effort needed to move the trays through the furnace. The reducing atmosphere may be provided by a town gas endothermic generator, but more usually a hydrogen/nitrogen mixture from a cracked ammonia generator is used. Time at temperature may vary from a few minutes to several hours but is usually between ½-2 hours. Although gas has been used on a laboratory scale to attain the temperature mentioned, all production furnaces in this country are electrically heated. The radiant tubes in common use for some of the processes already covered have too short a life to be considered practical, although the use of refractory instead of alloy tubes has been suggested as a means to overcome this drawback and I should be most interested to hear from anyone who has experience of such a system.

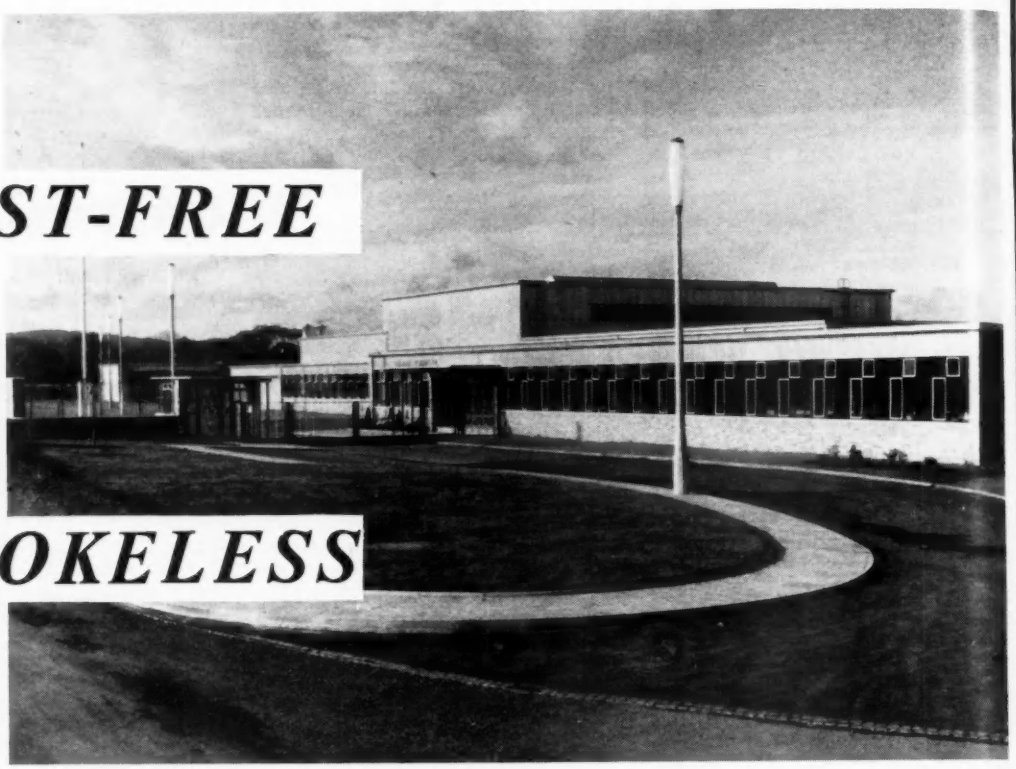
So far the processes discussed represent changes which are completed under controlled atmosphere conditions, with the finished product emerging in a relatively cold state. With forging and hot stamping, extrusion or rolling, the article is removed from the furnace at red heat, the heating being only part of each process. Under these circumstances they could justifiably be omitted from the paper, but the fairly recent introduction of a system enabling economic scale free heating under controlled atmosphere conditions is of current interest and worthy of attention. In the past, reducing conditions have been atttained in direct fired furnaces by ensuring incomplete combustion of the fuel and as a result the exit gases contained both sensible and chemical heat. Sometimes recuperation recovered part of the sensible heat, but more usually both this, and the chemical heat contained in the unburnt gases, were entirely lost. By completing the combustion in an external heat interchanger, the primary air may be preheated to 1,000°C., with the final waste flue gases leaving the interchanger at as low a temperature as 200°C. About half the air which is necessary for complete combustion is provided to the burners within the furnace itself so that the resulting atmosphere is in the rich exothermic range. This is sufficiently reducing to ensure scale free heating up to temperatures of 1,350°C which is well above that obtainable by the existing radiant tube design, employed for other controlled atmosphere heating.

Sited on top of the furnace are the heat interchangers, or thermal pulsators as they are known, the number of these used depending upon the size of the furnace. It is claimed that they may be tted to either existing or new plant. Apart from the benefits of freedom from scale formation there are the added advantages that the furnace is direct fired, with improved efficiency over indirect heating, and the need for a separate atmosphere generator is eliminated.

Enormous Prospects

The prospects for gas in the field of Controlled Atmospheres are enormous and we already have a reasonable share of the load in the first four processes discussed. Before the introduction of alloy radiant tubes it was not thought possible to use town gas as the heating source and electricity had the field more or less to itself for a number of years. This is no longer the case as can be seen from the number of gas heated plants which have been installed within the last few years. Continued sales promotion and education of consultants could materially assist in swinging the pendulum even further in our direction. The benefits accruing from heat processing under controlled atmosphere conditions are worthy of consideration by all firms engaged in the manufacture of metal components. There are limitations, of course, and the more conventional oven and portable cover furnaces, which have been faithful servants for many years, will probably never be entirely displaced. Even so, it is to be expected that furnaces specially designed for clean and closely controlled heat processing will oust many of these in the near future. In the last three processes discussed—nitriding, brazing and sintering—the heating and atmosphere requirements are all straightforward and clearly defined. For nitriding we can offer suitably designed furnaces, and even convert existing ones, but brazing and sintering present rather greater difficulties. We can already provide temperatures up to about 1,000°C., which is sufficient for brazing with a flux and for sintering certain non-ferrous metals. A slight advance in design to attain 1,150°C. or thereabouts, without the need for constant replacement of tubes, could give us a much greater share of both.

DUST-FREE SMOKELESS



these words are imperatives in lens-making — one reason why gas is used at St. Asaph

THE benefits to be gained from the use of refined smokeless fuels are seen at the new Chance-Pilkington lens factory in North Wales which was brought into production last November.

At this factory, which has been built in the country about 1½ miles from the small cathedral city of St. Asaph in Flintshire, it was important that the activities of glass making should be carried on in a dust free atmosphere under conditions of smokelessness.

For these conditions to be met, a site in the countryside away from the dusty smoke-laden atmosphere of South Lancashire, the traditional centre of glass making, had to be found.

It was also necessary to have adequate fuel supplies to hand, and before any decision as to a suitable site could be made, a guaranteed supply of at least 5 mill. cu.ft. of gas per week was a necessity. An adequate supply of electrical power had also to be available.

The Board of Trade were approached and suggestions were made for sites on the North East coast, North Lancashire, Central Lancashire, Northern Ireland and the North Wales coast.

Other considerations which had to be taken into account were: At any given site land had to be available for future expansion; the district had to have the amenities to attract the necessary technologists and scientists; and labour had to be easily available in the district.

Since such conditions could be met at St. Asaph, and because it was within easy reach of Pilkington's main glass-making factory at St. Helens and good rail connections between North Wales, the Midlands and London, the site at St. Asaph was chosen.

The laying of the North Wales grid connecting the gas undertakings along the North Wales coast with the Maelor gasworks at Wrexham and the coke oven plant at Queensferry would assure an adequate supply of gas and supplies of electrical power could be made available in the district.

At this factory are manufactured optical and ophthalmic glasses. Their production demands a very rigid control of temperature conditions both in the glass melting tanks and in the channels through which the molten glass passes to the moulding machines. The moulding machines themselves must be kept at a high enough temperature to prevent a too-rapid cooling of the molten glass until it has entered the annealing lehr. The glass-melting tanks which have been supplied by Corning Glass Incorporated of New York are gas heated and thermostatically controlled. The molten glass of a viscosity depending on the temperature of the glass leaving the melting tanks, passes down a vertical electrically heated tube, the temperature of which must be controlled to within ±1°C. This ensures that the viscosity of the glass remains constant so that the weight of glass delivered to the moulding machine for pressing into an ophthalmic blank, or a 'gob' for

optical blanks also remains absolutely constant.

The moulds are gas heated to prevent the molten glass becoming too viscous for pressing and after pressing, cooling too rapidly before it enters the gas heated annealing lehr. As the blanks pass out of the lehr they are inspected. Any blanks which show an obvious fault in the glass, such as entrapped air or discoloration are immediately thrown out by the inspector but, since the dimensional tolerances must be maintained within very fine limits, sample blanks are taken every half hour and tested in the laboratory.

The weight of the 'gobs' is kept to about 40 grams, but the ophthalmic blanks which will be ground directly to spectacle lenses must have their periphery and thickness maintained to within .22 mm., equivalent to a weight of 1 gram of glass. To do this the tolerance of the moulds has to be kept within .001 in.

The output of blanks of both types amounts to 60 mill. a year. Since the factory came into production the optical glass made there has proved to be of superlative internal quality and colour. Later on it is proposed to manufacture large shielding windows, 4 ft. 6 in. by 3 in. by 4 in. thick, polished on both faces, for radiation protection in nuclear energy work.

The factory itself, which also includes administrative offices and a well equipped canteen, is a single-storey building set amid green lawns. It is heated throughout by a gas fired central heating system, and to combine retention of the heat in the building with the need for a very high standard of natural lighting in both the offices and the factory, the very large window space is doubled glazed throughout. Special anti-sun glass has been used on the south side of the works.

The central heating unit has been supplied by Bouellat Engineering Ltd., of London, and is one of their 'B' type boilers, adapted for gas firing with Selas radiant diffusion flame burners. It has an output rating of 2 mill. B.t.u. per hour and is automatically controlled for water temperature, safe lighting procedure and flame failure by Protectoglow remote control equipment from a central panel. Hot water is pumped to the offices and canteen through orthodox convector radiators. All circulating circuits are constructed of welded steel pipe. The factory itself is similarly heated by overhead heating panels suspended just below ceiling level.

Modern smokeless fuels are making possible the building of factories away from the grime and dirt of the traditional industrial areas.

Raw materials for glass making are carefully weighed in the hygienic batch mixing and weighing room.

Above: *An operative keeps a careful control of the temperature of the melting units by means of apparatus in the instrument room.* **Right:** *This general view of the works shows the annealing lehrs and inspection of ophthalmic blanks. Sample blanks are taken every half hour and tested in the laboratory in order to contain the dimensional tolerances within fine limits.*

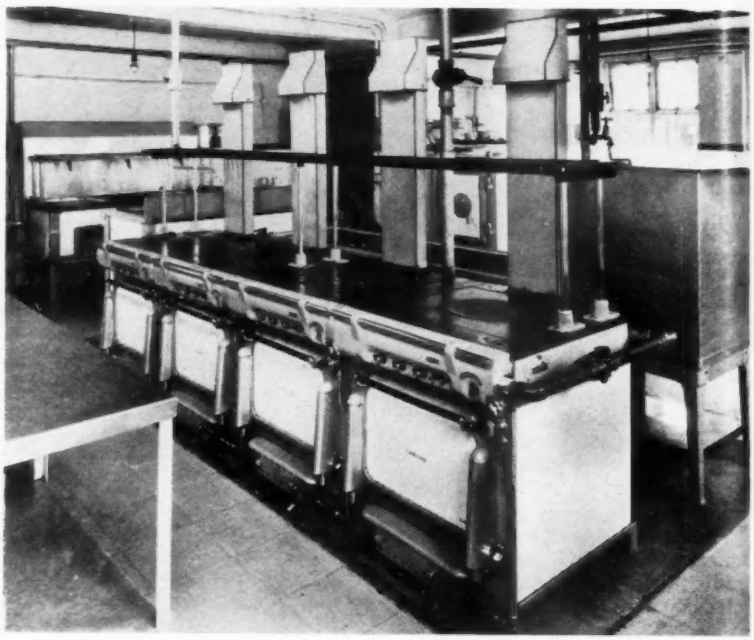
BETTER INDUSTRIAL CATERING

Scrap the Word Canteen, Says 'Gastronome'

MANY kitchens catering for workers in industry, do not come up to the standard that commercial kitchens in general have attained. The reason this may be summed up under three headings:

1, Management indifference to staff catering; 2, lack of training among catering management staff; and 3, obsolete or ill chosen kitchen equipment and appliances.

Poor management is not always created by lack of interest in the welfare of workers; it applies mainly to the few who only supply food to obtain staff which is mostly casual or seasonal. It is perhaps caused by the lack of an inspired lead which in turn may be due to inadequate information on the important subject of staff catering.



The kitchen of an industrial restaurant catering for 150 people.

In Perspective

This can be combated and put into perspective by organisations such as the Industrial Welfare Association, and by interested industries, in particular our own industry, which can give advice to industrial caterers.

In the case of inexperienced and untrained catering personnel we can do little except recommend the activities of the associated trade organisations such as the Industrial Catering Association, the Catering Managers' Association, and the educational work of the Hotel and Catering Institute.

The problem of inadequate kitchen equipment and appliances can be solved by the gas industry. In so doing we must ally it to the highest possible standard because staff catering must be immune from criticism, be ever popular, and be looked upon by the staff as a tribute from the management to their labour and dignity—two assets that most workers have and most managements recognise.

An extensive survey into this class of catering is not possible here but a lead can be given in the approach to the problem.

First, the term canteen should be abolished in favour of more dignified expressions such as staff restaurant or staff cafeteria. Nothing is more likely to undermine the promotion of first rate service than the term canteen. It conjures up visions of mediocre food and surroundings.

A glance at the industrial kitchen will reveal that the cooking and food service equipment will, apart from being gas heated, be identical to that favoured in the kitchens of leading hotels and restaurants—obviously, because this is the only approach to a top rate large-scale food service.

Design centres round the solid plate top cooker made up in units to form a central range or a wall range. This is the basic equipment for good cooking and though supplementary appliances such as frying ranges and steaming ovens are necessary, the more general type of cooking takes place on this range.

This industrial kitchen caters for large numbers.

Success Story

Our interest in this class of cooker is based on its success in its close resemblance to the traditional coal range, the supremacy of gas over that fuel and indeed any other fuel feeding solid top plate ranges, and the pos-

sible immunity from competition in years to come, but above all, because it is the right equipment on which to found a high standard kitchen.

The important features are fuel economy in dealing with volume top cooking; ready response of the heated top from 1,000° F., in the centre to 450° F., at the sides of the units; immense reserve of heat enabling last minute final cooking; and the ease of moving heavy cooking pots across the smooth top.

Prejudice

A feature of the oven usually associated with this type of range is its close resemblance to the indirect fired oven used with baking, making cooking on all shelves of the oven possible. Width and depth with a maximum food capacity and minimum height, make it most attractive to the first class kitchen.

There is a certain amount of prejudice against this type of cooking range due to inexperience in the large-scale cooking profession; it can be ruled out as having no serious foundation. But a point does arise: It would be an advantage if some initial briefing on the use of this equipment could be given by an adviser similar to the home service advisers of our industry. Another criticism of waste of gas cannot be accepted with a sound kitchen organisation.

Much development has gone into the range and an alternative method of firing the hotplates is perhaps the most important. Design has been streamlined and stainless steel and coloured vitreous enamel are used extensively. The range made up in units can also be increased in versatility by the addition of a bain marie section, grills and salamanders, and deep fat frying units.

The emphasis on kitchen design and improvement in staff catering does not necessarily revolve around this range, but it is a feature consistent with such an approach. It should be boosted as should the proper training of catering personnel. This class of range is proof against competition and is the first requirement of the top class kitchen—such kitchens are wanted in industry.

The kitchen of a hotel in Torquay.

PARKINSON DEMONSTRATION FLEET

A fleet of vehicles like this one is being put at the disposal of each of the gas boards by Parkinson Cowan Industrial Products. The boards will be able to collaborate with Parkinson representatives to demonstrate the principle of the Parkinson-Schwank radiant heater. A demonstration takes only two minutes.

Tunnel Kilns for CERAMICS

IN their latest brochure, Gibbons Bros., Ltd., of Dudley, give a short description of the tunnel kilns they are building for the firing of ceramics. Each type of kiln described and illustrated by photographs of recent installations can be fired by town gas, producer gas or fuel oil as is most convenient.

The firing of all types of ceramics can be carried out by the appropriate design of tunnel kiln and include sanitary ware, glost table ware, wall tiles, refractories and even red clay goods.

The firing of the latter in this type of kiln is a new application of the tunnel kiln. Formerly it was considered too expensive a means of firing a comparatively cheap product, but the rise in cost of labour and fuel is changing this opinion.

Noticeable from the illustrations of recent installations is the large scale on which ceramics can be fired by means of the tunnel kiln. In fact, such a kiln built for a firm of sanitary ware manufacturers is considered the longest Dressler-type kiln ever built.

Summer-time Steam Raising
—*a gas-fired installation*

Geoffrey Fitton

B.Sc., M. Inst. Gas E., M. Inst. F., Engineer and Manager, Neath Undertaking

GAVE THIS PAPER TO THE WALES AND MON. SECTION, I.G.E., SPRING MEETING LAST MONTH

THE development of the space heating load inevitably widens the difference between summer and winter demand and therefore increases the need to obtain, wherever possible, such loads as are confined to the summer months.

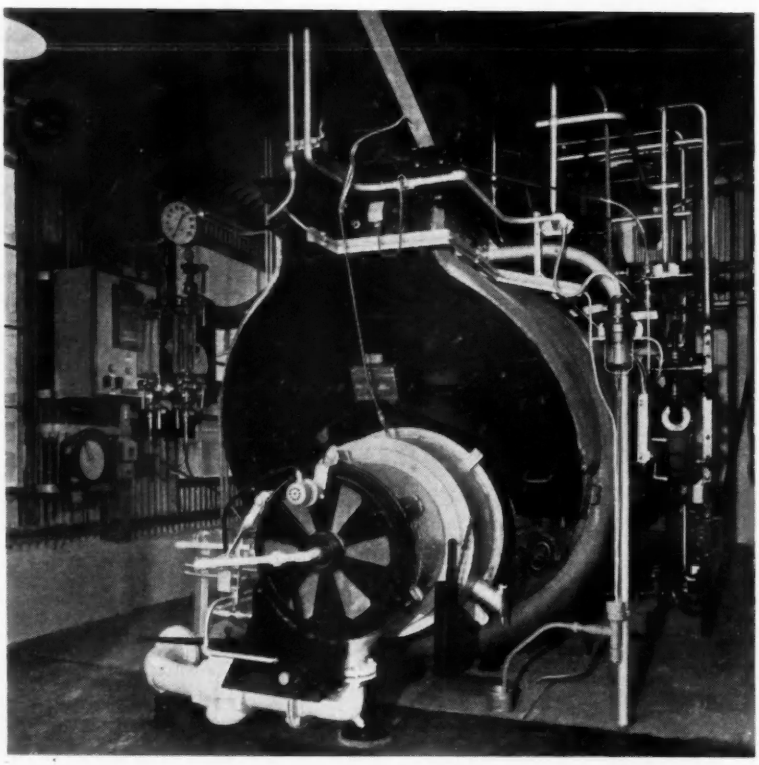
In the 1958 Presidential Address to the Institution of Gas Engineers, Dr. J. Burns referred to recent trends in seasonal gas consumption in the North Thames area and in Great Britain as a whole. He showed how in both cases the summer/winter differential arising from the space heating load has progressively widened during the past five years. A drop in atmospheric temperature to 30°F. during the winter 1955-6 corresponded to an increase in weekly output in the North Thames area of 200 mill. cu.ft. (7½%) above the figures for 1951-2, only a small fraction being all the year round load as shown by changes in the summer output.

The national statistics show similar trends for the country as a whole and indicate an increase in the differential output due to temperature of some 1,300 mill. cu.ft. (8%). These trends are particularly important in places where coke oven gas supplies are available all the year round.

If gas is to compete successfully for such loads, the installations must be designed and maintained to produce optimum operating efficiency and the installation described in this paper is submitted as typical of the best practice in design and instrumentation, the latter being specially necessary to the maintenance of good operating results.

The Neath factory of the Metal Box Company mass-produces components for open top cans and carries out large-scale printing and lacquering work on a portion of the output and, for the latter operations, there is an extensive utilisation of gas in a battery of large conveyor type drying opens. The factory, except for the administration blocks, is a single storey building, covering an area of approximately 350,000 sq. ft.

The space heating installation consists of a combination of radiators and direct air heaters, all of which are supplied with steam at 100 lb. p.s.i. In addition to the main space heating requirements, there are other subsidiary steam demands for hot water calorifiers and for minor process items. The main boiler installation is coal-fired and comprises three Economic type boilers with chain grate stokers, rated at 12,250 lb. of steam per hour each.



The fully-automatic gas-fired boiler at the Neath factory of the Metal Box Company.

Line Losses Constant

The use of such an installation during the summer months is obviously uneconomic but, in addition to excessive operating costs, maintenance work is greatly hampered when the entire installation cannot be closed down during this period. The line losses between the boiler house and main factory buildings remain constant, irrespective of demand, and

amount to 1,000-1,200 lb. of steam per hour.

In relation to summer demand these losses come to represent a substantial proportion of the steam raised on the coal-fired boilers. In the light of these considerations and as gas supplies in adequate quantities were already provided within the factory, it was decided to install a fully automatic gas-fired boiler to meet the steam requirements from April to September each year.

The gas-fired boiler is of the horizontal two-pass type, the shell being 14 ft. 6 in. long by 5 ft. 6 in. diameter, and has a steam rating of 2,500 lb. per hour at 100 lb. p.s.i. The burner equipment used on this installation is a Gako burner having a capacity of 7,000 cu.ft. of gas per hour. This burner consists fundamentally of a large refractory disc, approximately 15 in. in diameter, set within a steel sleeve.

The down stream edge of the disc is fairly tight inside the sleeve, but for the upstream three-quarters of its length its diameter is slightly reduced from a shoulder, so that a narrow annular space is formed between the outer edge of the disc and the sleeve. Twelve venturi-shaped holes are formed through the material of the disc, tapering from approximately 3¼ in. to 3 in. diam. and having their narrower ends upstream.

The gas is fed into the annular space and is then drawn through the holes by the pull of the induced draught fan. The effect of this type of burner is to produce a slight swirling motion of the flame, the length of which can be adjusted by appropriate relative settings of the gas rate and air louvres. The pilot burner is completely independent of the main burner and has a rating of approximately 250 cu.ft. per hour.

An induced draught fan is provided and the inlet air louvre is fitted with motorised valves so that when the thermostat has interrupted the gas flow to the burner, the amount of cold air drawn into the combustion chamber is kept to a minimum.

No Scale Formation

All condensate is retained in the system so that the feed water is well preheated, but its temperature is obviously greater in winter when the full installation is in use than on the relatively small steam load in summer. The feed water temperature generally available to the gas-fired boiler is of the order of 140°F. Returned condensate represents 95% of the feed water, the balance being treated town water. Under these conditions it is relatively easy to maintain zero hardness conditions in the boiler water and scale formation is virtually non-existent.

The main gas supply is governed down to 6 in. w.g. by a standard type of Bryan Donkin low pressure governor of 4 in. diam., but thereafter all gas controls (with the exception of the hand trimming cocks for the pilot and main burners) are integrated with a Honeywell Brown Protectoglo unit, Model N, No. 5100.

The principal function of the unit is, of course, to operate on flame failure and so to prevent any hazard from unburnt gas after accidental flame interruption. It operates on the flame conduction principle by which an electric current is made to flow from an electrode through the flame on to the metal of the burner, and, after suitable amplification to operate a relay interlinked with other controls. This system has the advantage over others that it can differentiate between a flame and hot gases and has, therefore, an instantaneous response to flame failure.

Time Lapse

The other explosion hazard, which could arise due to an accumulation of gas during periods of shut down, e.g., from a leaking valve, is catered for manually in this instance by allowing a lapse of time, during which the induced draught fan is allowed to run before the lighting torch is applied.

To effect the necessary integration with the controls mentioned later, it is necessary to use solenoid-operated pilot and main gas valves. The former is a directly operated solenoid valve but the latter is a Perl diaphragm-operated valve, in which the solenoid opens or closes a weep from the upstream side, so that the space above the diaphragm is pressurised or vented as required, the rate of movement of the main valve being controlled by the permitted rate of weep. In the event of failure of electricity supply both the pilot and main gas valves close.

The use of such an arrangement only would mean that the unit must operate on an on/off cycle based on the full-on rating of the burner, and under such conditions it has been found that the efficiency of the boiler is not so good as when the gas rate is adjusted to the load. This arises, of course, because a certain amount of cooling effect inevitably takes place due to the drawing in of some cold air through the boiler during stand-by periods.

It is possible to meet this condition in two ways, either by the use of the hand-operated valve to the main burners or, alternatively, by the use of a modulating control. It has been found in practice that the former method is too inflexible, as sudden demands by the calorifiers can drop the steam pressure in the boiler below working limits, unless such demand is anticipated and this is not always possible. A modulating control valve has, therefore, been installed in parallel to the main Perl diaphragm-operated valve mentioned above.

The method of operation now generally adopted is a combination of the use of the modulating valve with the hand trim of the main burners. This has become possible through experience of the likely day-to-day maximum and minimum steam demand.

The following controls are electrically interconnected with the Protectoglo unit: (a) Electrically-driven induced draught fan; (b) electrically-driven feed water pump, actuated by a Mobrey control; (c) electric drive to air louvres; (d) electric impulse to pilot gas valve; (e) electric impulse to main gas valve; (f) on/off steam pressure control switch; (g) high steam pressure limit switch; (h) Mobrey control acting as a low water switch; (i) low gas pressure switch.

The last three of these controls operate a relay to close down the whole installation and to give a visual and audible alarm. The Mobrey control is a magnetic device, manufactured by Ronald Trist, and has the great advantage of being entirely glandless, the electrical contacts being magnetically operated through the wall of the float chamber.

Audible Alarm

There are also signal lights to indicate that the induced draught fan motor and the feed water pump motor are running. In addition to the usual boiler mountings, a Hilo audible alarm is installed to give prior warning of the likelihood of a tripping of the entire unit due to low water.

The sequence of operations when lighting up the boiler is as follows:—The switching on of the main power circuit starts the fan and the pump motors after which a time lag is allowed, in order that any gas within the combustion space of the boiler has time to clear. A paraffin-impregnated torch is then applied and the push button depressed, thus opening the gas valve on the pilot line. The ignition of the pilot establishes flame conduction and the electrical relays close the circuit to enable the main gas valve to open.

Gas cannot, as yet, pass to the main burners as the hand trim cock is left in the closed position. But the fact that the boiler is calling for heat will cause the solenoid valve on the main gas line to open and also will open the

louvres on the combustion chamber inlet.

Once the pilot flame is burning steadily and flame conduction has been established the press button can be released and the control unit will take over. Gas is then admitted to the main burner by opening the hand trim valve gradually to the chosen gas rate. Thereafter, the unit will take over normal control, within the pressure limits set on the on/off steam pressure control switch.

Adequately Covered

This control may be effected by direct on/off operation of the main gas valve in conjunction with the motorised air louvres or by the operation of the modulating valve, which is in parallel with it. The switching off of the fan will close the whole unit down through the safety relays described above.

The unit is very adequately covered with indicating and recording instruments of various types. These are (a) Steam flow meter and integrator having a range of 0 to 2,500 lb. of steam per hour; (b) hydrostatic gauge to indicate the liquid level of the hotwell; (c) CO_2 recorder connected to the foot of the stack; (d) draught gauges at the air inlet to the main burner and at the flue gas exit from the boiler to the induced gas fan; (e) thermo-couple type recording pyrometers in the combustion chamber and at the foot of the stack; (f) gas pressure gauge and recorder on the outlet of the main gas governor; (g) Bailey type meter indicating gas flow and, by integration, gas consumption connected to the up-stream side of the main governor; and (h) a timing device is incorporated showing, by integration, the relation of the total time during which the fan is running (which represents the time the boiler is in commission) to the total time that gas is flowing to the main burners. From this can be deduced the percentage of the hours during which the boiler is on pilot rate and therefore under standby conditions.

Excellent Results

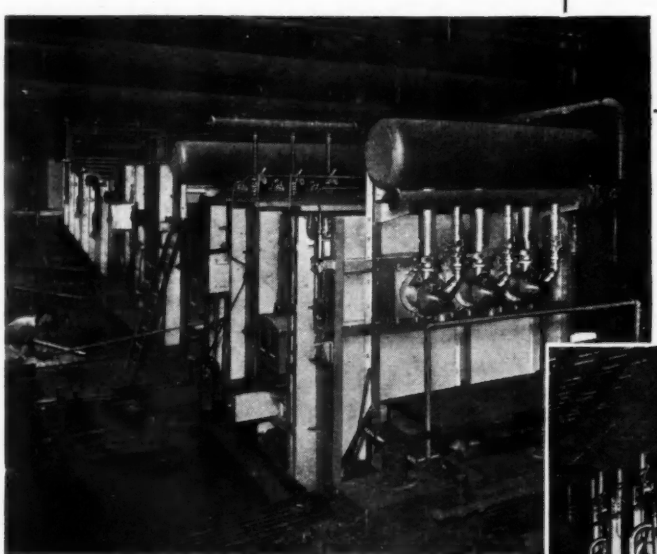
The following summary of a typical day's log sheet shows the excellent operating results, which are consistently obtained from this installation. These results refer to a day when the boiler was operating entirely on modulating control so that the period on pilot rate was nil.

Hours of operation ..	24
Hours on stand-by ..	Nil
Water evaporated ..	33,025 lb.
Water evaporated from and at 212°F.	37,000
Gas consumed	119,200 cu. ft.
Gas consumption per lb. of steam as raised ..	3.61 cu. ft.
Gas consumption per lb. of steam from and at 212°F.	3.22 cu. ft.
CO_2 Maximum	10.0%
Minimum	8.5%
Mean	9.05%

The gas consumption mentioned above is typical of the operation throughout the summer, with the obvious exception of the period of annual holiday, so that the weekly gas consumption of the installation is of the order of 600,000 to 700,000 cu.ft.

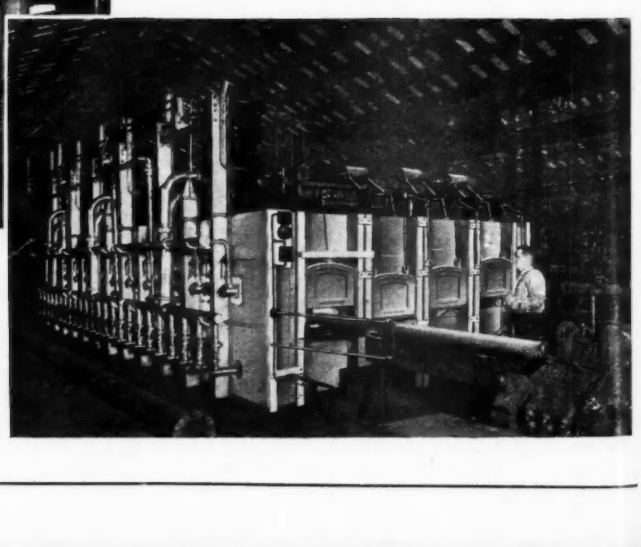
Figures given below show the comparative and competitive position of the gas fired boiler in relation to those of the coal fired installation when this becomes over-sized in relation to its load. Another factor which is of particular significance in this instance is the dis-proportionate extent during summer loads of the line and other extraneous losses due to the relative remoteness of the coal-fired boilerhouse.

The summer load costs for the coal-fired boilers are, of course hypotheti-



FURNACES FOR INDUSTRY

The illustrations show furnaces supplied to the Tube Mill at Babcock & Wilcox Ltd., at Dumbarton. They include a gas-fired Billet Heating Furnace, 6′ × 70′ (upper illustration). A Roll Down Tube Reheating Furnace, 35′ × 10′ 9″ (lower illustration).



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cal, but are based on working practice before the gas fired boiler was installed. In order to show the effect of the extraneous losses arising they are worked out both in terms of steam raised and steam used.

In all cases depreciation and maintenance costs are omitted in order to preserve a clear comparison between operating costs. It is obvious that the extent of extra maintenance arising from the use of the coal fired boilers during the summer period under light load conditions would be only marginal. The gas fired boiler has only required routine attention to its control equipment and accessories.

All costs refer to an average over a 13-week period.

(1) Coal-fired boilers operating under normal load (actual costs for 3 months ending December, 1957).

Steam raised	18,775,000 lb.
Steam as raised per lb. of fuel	9.1 lb.
Costs—	Per 1,000 lb. of steam.
Coal (including handling, demurrage, etc.) ..	6/5.7
Labour (including boiler cleaning, ash disposal, etc.)	1/8.7
Power	3.6
	8/6.0

(2) Coal-fired boiler operating under hypothetical summer load conditions.

Steam raised		4,290,000 lb.
Steam used		2,210,000 lb.
Steam as raised per lb. of fuel		7.4 lb.
	Per 1,000 lb. of steam.	
	Raised	Used
Coal (including handling, demurrage, etc.)	7/4.7	14/3.7
Labour (including boiler cleaning, ash disposal, etc.) ..	7/3.3	14/0.3
Power	9.8	1/7.8
	15/5.8	29/11.8

(3) Gas-fired boiler.

	Per 1,000 lb. of steam
Gas	16/3.8
Labour (allocation for part-time supervision and cleaning, etc.)	1/3.2
Power	2.2
	17/9.2

It will be seen from the foregoing that this load is equivalent to approximately 12 mill. cu.ft. in each summer season and, therefore, is of great value in helping to smooth out the seasonal variations, which inevitably arise from other classes of business. It is hoped that the figures quoted above will show the efficiency which can be obtained in well equipped and well instrumented units of this type and will therefore be helpful to members of this District Section in developing this sort of load.

It is desired to record sincere appreciation to the Metal Box Company and especially to Mr. G. A. Higham, Factory Manager of their Neath factory for permission to present this paper and for granting access to the relevant information and records; also to the valuable help in its preparation which was given by Mr. J. C. Dixon, Plant and Maintenance Engineer of the Company's Neath factory.

DISCUSSION

Mr. W. H. Tarn (Industrial and Commercial Gas Engineer, Wales Gas Board) said that they were giving much consideration to direct heating in the food and chemical industries. The author's paper had given an excellent example of how summer time loads were obtainable; on the other hand he felt that a certain type of work could be done by direct heating at a lower cost than steam. He noted that the author had preferred the modulating control to the on/off control; there was a school of thought which considered that the latter was better. One of the difficulties which they as a Board had to face was the fact that the winter heating load was building up far more rapidly than the base load. For every four or five therms sold in winter for this purpose, only one therm was sold in summer. Unfortunately, the industry was not yet sold on the idea of hot water installations in schools operating on gas during the April-September period.

Mr. Darrell W. Rees (Glanelly) related how at one of the largest bakeries in his area there had been a blowout with a Cochrane vertical boiler. They had installed a Flame Control boiler within two days, complete with all the controls referred to except the Mowbrey control. The baker naturally bought gas at the bakers' rate, which was in fact the lowest tariff block. For one month they kept an accurate check and found that the cost of gas for this boiler was £35, whereas the cost operating on coal would have been £60. Mr. Rees also told how the British-American Optical Company softened the wax fixes on lens blocks with hot water boiled by solid fuel. The Board had been asked to put in gas firing and had made a counter proposal that the job be done by direct heating. They had recently installed a travelling furnace utilising 48 Schwank burners, and operating costs had been nearly halved.

Mr. T. Mervyn Jones (Chairman, Wales Gas Board) congratulated the author on a paper which went a long way towards indicating how a valuable sumertime load could be gained. They were reaching a stage when disposal of gas in the summer had reached the proportions of a major problem. He hoped that members would be encouraged by the success of the installation described by Mr. Fitton and would do their utmost to achieve a level load factor.

Mr. E. M. Edwards, President of the Institution of Gas Engineers (Cardiff), said that since 1948 annual gas sales had increased by more than 50%, but the maximum weekly demand had increased by 62% and the maximum daily demand by 73%. This underlined their great need for an improvement in the load factor. He felt that they would do well on many gasworks to enquire what was the cost per therm of steam delivered to the point of use, and then what was the cost of that steam per therm usefully applied; they might well have a shock if they examined this point.

Mr. S. L. Wright (Cardiff) stressed the importance of siting a boiler at the point of use, and described his experience with a boiler at the Point of Ayr station—an installation which had proved to be a 'fit and forget' affair. He asked what was the accuracy of the Bailey type meter. Was there a master meter and to what extent did it vary with the rate of gas? Were the gas and air rates automatically controlled? If the CO_2 recorder did not give good results, what could one do?

Mr. H. B. Kendrick (Conway) asked how the author had arrived at the quantity of steam used; he had not stated the price of coal or the price at which gas had been sold for this purpose.

Mr. J. Powdrill (Cardiff) said that a new coke oven gas contract came into operation on January 1, 1956, for G.K.I.S. to supply 84 mill. cu.ft. of gas per week to Grangetown gasworks; the provisions included for a charge of 7½d. per thousand cu.ft. for quantities below 84 mill. cu.ft. per week. As a result, gas had become available at Grangetown in quantities in excess of normal requirements during the summer of 1956. This excess could not be exported into the Eastern Gas Grid which already had adequate supplies to meet the summer load and the possibility of using the surplus gas for steam raising at the Grangetown works was therefore investigated. There were eight Lancashire boilers in operation in 1956, and it was decided to convert four of these to gas firing, with an anticipated maximum gas consumption of 1¼ mill. cu.ft. per day, or 8¾ mill. cu.ft. per week.

A venturi type burner was designed by the Industrial Department, and two were fitted to the first boiler to be

modified. This arrangement was not entirely satisfactory, being made of welded steel plate which tended to warp when hot. A second type of burner was designed and fitted to the next three boilers, which was of drum type, the drum fitting the fire tube of the boiler; this proved to be very satisfactory. Air tubes of 2 in. diam. were welded through the drum and four holes of $\frac{7}{8}$ in. diam. were drilled in the drum face around each air tube, to admit gas to the boiler.

Rapid Changeover

By the summer of 1957 steam demand on the works had fallen considerably, following the completion of the first stage of the reorganisation of the fuel and power arrangements on the works, and only two Lancashire boilers were required. It was necessary to be able to use gas or solid fuel on these, and to effect rapid changeover. A 6-in. gas main was run overhead, above the four fire tubes of the two Lancashire boilers to be converted. A 3-in. connector was brought down to each fire tube and finished in a half circle above the charging door. Each end plate was drilled in five places above the door and $1\frac{1}{4}$-in. tubes inserted into the fire tube for the 3-in. gas main, each 3-in. tube being controlled by a gas valve. No flame failure devices were installed, as a certain amount of solid fuel was always fired into the boilers. No governors were installed on the gas supply, as these boilers were under the constant supervision of a boilerman.

The capital costs had deliberately been kept to a minimum as it was anticipated that by the summer of 1959 little steam raising would be required during the summer period, at Grangetown. These gas firing units on the two boilers allowed up to 600,000 cu.ft. of gas to be used per day. The quantities of gas used for boiler firing were: Summer, 1956, 96 mill. cu.ft.; summer, 1957, 47 mill. cu.ft.

Increased Efficiency

The efficiency of steam raising with solid fuel at Grangetown was of the order of 47%. The efficiency during the summer of 1957 using over 90% gas firing, was increased to an average of 66.8%, i.e., 1 ton of coal was replaced by 205 therms of gas. This coal was costing £5 per ton delivered, so that the value of one therm of gas as boiler fuel was approximately 6d. A part of the coal being used was of low grade.

Replying, **Mr. Fitton** stressed the necessity of boiler design being 100% right for the job. Although the coal fired boiler installation was 90% efficient when operating on a good load factor in winter, steam still cost 8s. 6d. per 1,000 lb. at the boiler. Roughly speaking, 1,000 lb. of steam could be taken as equal to 10 therms. However, the important thing was to get the load for gas whether it be via steam or by direct heating. In reply to Mr. Tarn's query concerning the control, it was true that an on/off control was usual for such items as hot water boilers, but in this case the boiler was equipped with an induced draught fan and the modulating control had been used. To Mr. Rees he would say that unless the solid fuel boiler was very inefficient, it was not possible to get steam at the point of use cheaper with gas. With regard to Mr. Wright's point about boiler siting, the presence of a large coal fired boiler with the inevitable ash, dust, etc., near a factory carrying out such work as tinplate printing, was unthinkable. In this case the gas boiler had been put in a little building adjacent to the factory. He regretted that he could not answer the question about the Bailey meter. No meter was available separately on the line to the gas fired boiler; the figures quoted were integrated figures on the Bailey meter. The gas and air proportions were not automatically controlled; the ratios were manually set to give optimum CO_2 percentage and the CO_2 recorder was used to ensure the maintenance of these conditions. Replying to Mr. Kendrick he said that the steam utilisation was assessed from the quantity of water evaporated; The Metal Box Company, with whom the Board had a special contract, bought gas at about $11\frac{1}{2}$d. a therm. To Mr. Powdrill, whose conversion of Lancashire boilers he had found of considerable interest, he would say that the problem of utilisation of surplus coke oven gas was a very different aspect to the gaining of competitive loads. One could not hope to get the maximum efficiency with converted boilers—they must be purpose made if operating costs were to be kept within acceptable limits.

A vote of thanks was proposed by **Mr. O. P. Cronshaw** (Rhyl), seconded by **Mr. W. F. Edwards** (Port Talbot).

The Continental Press

SWEDISH CENTRAL HEATING SYSTEM

A NOVEL gas-fired, hot-air central-heating system with exhaust-heat recuperation has been developed by the Stockholm gas undertaking and various local authorities and firms. This unit is designed for heating a new series of 820 two-bedroom flats of 70 sq. m. floor area. The aim was to improve on the efficiency of existing systems so that these flats would cost no more to heat than previous flats of 56 sq. m.

The choice was between a central boiler for all the flats with hot-water radiators, a central boiler for high-pressure hot water with calorifiers in each flat, or unit air heating. The problem was considered from four points of view. The loss of heat through walls, loss through air changing, hot-water requirements and low unit efficiency. The first point was dealt with by improved building techniques, *e.g.*, insulated walls, triple windows, etc. The loss due to air changing could be recovered by a recuperator.

By using gas (and not oil) for the water heating, the flue gases from the water heater could be passed through this recuperator. The Swedes have a preference for air-conditioning systerms giving blown ventilation. The unit air-heating system with a recuperator to recover the heat both from the air discharged and from the water-heater's the flue gases proved the most efficient.

Ducting connections are made up inside a precast concrete block to form part of the wall between rooms; the various units are mounted compactly on one side of the block which forms an alcove in the bathroom. Access is obtained through a hinged door on which is mounted a mirror. The ducts are taken under the floors and the supply of fresh air and discharge of stale air is by means of a double-impeller electrically driven fan mounted under the roof. This fan is almost directly connected to the heat exchanger and thence by vertical ducts to the flat.

Hot air is supplied to all rooms except the kitchen, but since the stale air is sucked off from this latter room it is sufficiently air-conditioned.

An interesting point is that the individual meters are graduated directly in money and the landlord organisation of the flats is rated on a bulk tariff using a single meter for external payment. The air heater itself was developed by Messrs. Rohleder, of Stuttgart, Germany, since it was felt that insufficient experience was available in this field in Sweden.

J. Körting, Das Gas- und Wasserfach. Vol. 99. No. 13. March 28, 1958. p. 315.

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